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FINAL REPORT

ANALYSIS OF TACTICAL DATA LINKS USED BY THE DEPARTMENT OF DEFENSE

July 1977

Prepared for
DEFENSE ADVANCED RESEARCH PROJECTS AGENCY
1400 WILSON BOULEVARD
ARLINGTON, VIRGINIA 22209
OFFICE OF NAVAL RESEARCH
800 NORTH QUINCY STREET
ARLINGTON, VIRGINIA 22217

ARINC RESEARCH CORPORATION

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Defense Advanced Research Projects Agency
1400 Wilson Boulevard
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Arlington, Virginia 22217

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ARINC Research Corporation
a Subsidiary of Aeronautical Radio, Inc.
2551 Riva Road
Annapolis, Maryland 21401

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The objective of the study was to review and analyze DoD data link programs to define a minimum set of candidate standard data links which satisfy most current and future requirements, identify possible duplicative programs and assess the economic impact of data link standardization. In addition, the applicability of form-fit-function specifications for procurement of data links was investigated. —Next page

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The study developed six data link families that could be used as the basis to standardize future data link developments. The study also developed near term and far term data link standardization approaches.

Conclusions and recommendations were formulated concerning the approaches required to reduce data link proliferation and promote data link standardization.

ACKNOWLEDGMENT

ARINC Research Corporation acknowledges the assistance and direction provided by the ARINC Data Link Study Steering Group members: Mr. E. Greinke (DDR&E), Mr. L. Aarons (CNO), Lt. Col. Sollohub (DAMA), Lt. Col. J. Holt (AF/RDQPS), and Major R. Heath, II (AF/RDPE).

EXECUTIVE SUMMARY

1. BACKGROUND

A suspected high level of unwarranted duplication among data link programs, lack of standardization and interoperability among data link programs, lack of suitable data link quantitative measures, lack of data and criteria to provide the basis for Department of Defense (DoD)-wide management decisions, and lack of suitable definitions for data links versus communications/navigation links prompted the formation of a DoD Data Link Planning Committee in August 1974. This committee has representatives from all of the Military Services and Defense Agencies.

The DoD Data Link Planning Committee fully recognized the magnitude and nature of the problems and, in light of these problems, decided to contract with ARINC Research Corporation for engineering services to review and analyze the data link program area.

The specific objectives of the ARINC Research efforts were to support the Data Link Planning Committee as follows:

- Define a minimum set of candidate standard data links which satisfy most current and future requirements.
- Compare the existing set of data link development programs with the defined standard data link set and with each other in order to identify possible duplicative programs. Recommend possible management and design actions that could be implemented to reduce the proliferation of data links and enhance the transition to the standard data links.
- Investigate the applicability of F^3 specifications to procurement of data links.
- Identify and assess the economic impact of data link standardization.

The scope of the ARINC Research effort was limited to an investigation and analysis of tactical data links currently under development and future data links that have a definite stated requirement. Excluded from the study were the following:

- Existing operational systems

- Systems undergoing phaseout
- Fixed facility, long-distance point-to-point communications under the purview of the Director, Telecommunications and Command and Control Systems
- Acoustic links
- Any links utilizing transmission lines

2. ANALYSIS APPROACH

The approach used by ARINC Research Corporation in the investigation of the DoD data links was divided into three main subject areas: (1) the methodology for developing data link families, (2) the data link standardization assessment process, and (3) the economic analysis of the impact of standardization.

The methodology for developing data link families (Figure S-1) consisted of five main steps:

- <u>Defining the study ground rules and data base requirements</u>. The ground rules were developed in coordination with a DoD Steering Group to arrive at a common understanding of the assumptions, boundaries, and limitations of the study.

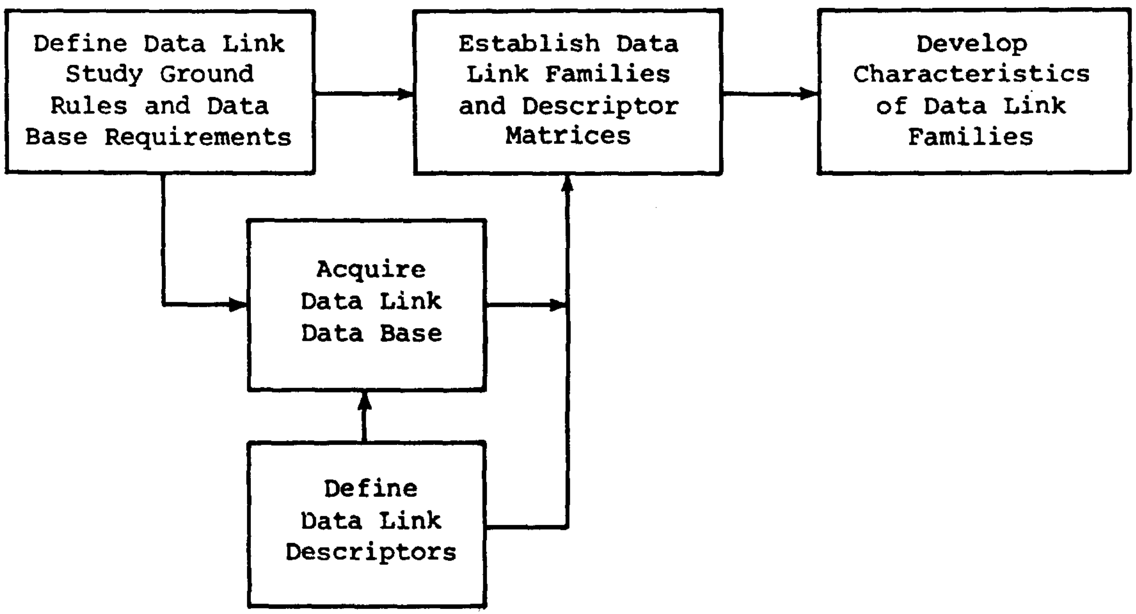


Figure S-1. METHODOLOGY FOR DEVELOPING STANDARD DATA LINK FAMILIES

- Acquiring the data base. The data base was acquired from 34 current systems consisting of 66 data links and 17 future systems consisting of 34 data links. The major sources from which information on data links was obtained were the data link planning notebooks, supplementary technical and cost information from the Military Services and data link contractors, documents provided by the Defense Documentation Center (DDC), and computer listings of systems with data links from the Electromagnetic Compatibility Analysis Center (ECAC).
- Defining a minimum set of data link descriptors. The minimum set of descriptors permitted categorization or grouping of data links with identical, or similar, descriptors.
- Establishing data link families. By an iterative process, the descriptors were used to categorize the data links into distinct families.
- Developing the characteristics of the data link families. The characteristics of the data link families were developed from analyses of the descriptors of the data links in each of the revised families. The six data link families are designated: (1) high frequency (HF) family, (2) low data rate family, (3) TDMA/Multiple-User family, (4) wide band family, (5) integrated expendable sensor family, and (6) electro-optical family.

The Data Link Standardization Assessment Process (Figure S-2) consisted of five main steps:

- Refinement of the characteristics of the data link systems within each family to permit an analysis of the data links to a greater depth than was permitted by the basic set of descriptors. The objective was to provide a basis for evaluating the incidence of program duplication and for refining the characteristics associated with each data link family.
- Development of generic data links to determine if a single data link could be defined that would be compatible with the characteristics of the data links within the family. The method used was to list the basic descriptors of the members of each family and, from the list, develop the composite technical characteristics of a generic data link. Each generic data link that evolved was defined by an envelope of technical characteristics that encompassed the characteristics of all of the data link systems within each of the families.
- Evaluation of the compatibility of each data link within a family with the generic family data link to develop options for the generic data link that would permit direct responsiveness to the specific characteristics of each data link within that family.
- Evaluation of the possibility of identifying a baseline data link within each family to determine if a data link system within a family could be used as the basic data link from which a generic data link could be developed.

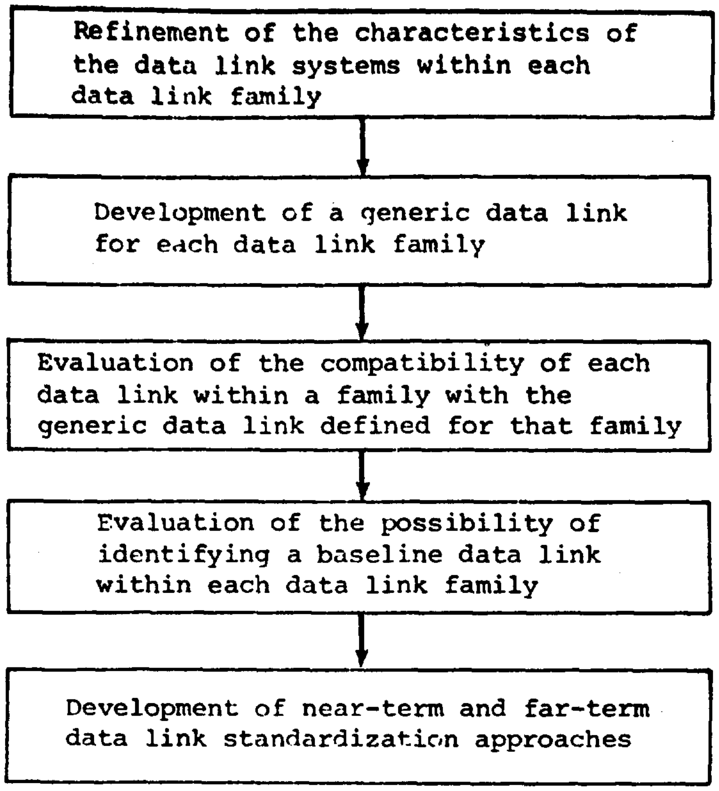


Figure S-2. DATA LINK STANDARDIZATION ASSESSMENT METHODOLOGY

- Development of near-term and far-term data link standardization approaches. The near-term approach attempts to identify methods to reduce data link proliferation, through analysis of existing programs to identify duplicative programs and programs that may be consolidated. The far-term approach involves the application of F^3 specifications to the generic data links associated with each family to provide the basis for data link standardization in the future.

An Economic Analysis was accomplished by selecting a candidate data link family and comparing the expected life-cycle cost of the generic data link with the combined life-cycle costs of all of the data links that comprise the candidate family. The life-cycle-cost model (LCCM) developed by ARINC Research for the Army user equipment associated with the NAVSTAR global positioning system was refined and used to generate the cost data for the economic analysis.

3. PRESENTATION AND EVALUATION OF RESULTS

The presentation and evaluation of results is divided into five major areas: definition and characterization of generic data links, standardization and commonality of data links, analysis of current data link programs, evaluation of future data link developments, and economic impact of standardization.

3.1 Definition and Characterization of Generic Data Links

Analysis of the data links within each family resulted in the identification and definition of generic data link functions that are separate from the functions that should be performed by the source and sink subsystems that use the data links.* The analysis also indicated that, in some applications, a wide range of standardization among systems can be achieved if the signal conditioner/reconditioner functions are excluded from the data link. Thus, a result of the analysis was the organization of generic data links into two categories: the basic data link and the extended data link, as shown in Figure S-3 -- a simplified block diagram of a typical generic data link. The basic data link includes a data modulator, a data demodulator, RF portions of the system (including antennas), and those controls necessary for the operation of the basic data link. The extended data link includes the basic data link functions as well as those of the signal conditioner and signal reconditioner.

An overall generic data link has been organized to encompass the characteristics of the generic data links for all of the families. However, certain data link functions will not apply to all the families and certain functions are included as options in the various data link families for both the basic and extended data links. Block diagrams were developed for the generic data links in each of the families.

3.2 Standardization and Commonality of Data Links

Standardization and commonality in the near-term may have to be limited, in some instances, to the basic data link interface. However, standardization in the far-term should be based on the extended data link interface when a new data link must be developed. In both the near-term and far-term cases, commonality and standardization across data link family boundaries can only be expected to be implemented at the basic data link interface. The assessment of the applicability of F^3 characteristics to the far-term generic data links indicates that the approach could be applied to many of the generic data links and their Line Replaceable Units (LRUs).

3.3 Analysis of Current Data Link Programs

Current data link programs were analyzed to determine if any programs were duplicative and should be terminated. New developmental data link programs were also analyzed to determine if any planned data links could be consolidated with other existing current data links. Analysis of current

*A data link family is defined as a collection of data links having a set of common characteristics. A generic data link is a single data link design concept that encompasses the characteristics of all of the data links within a family.

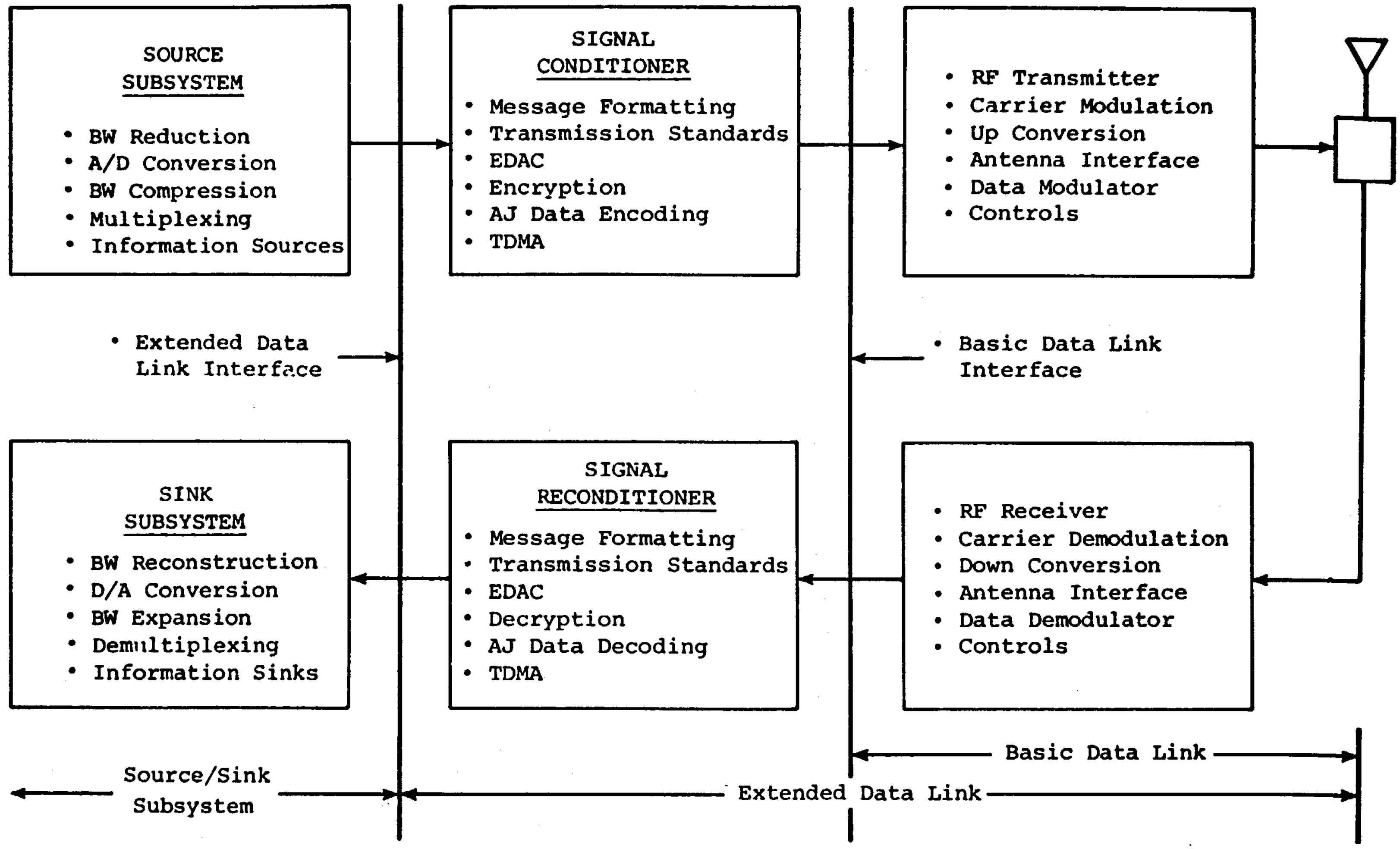


Figure S-3. SIMPLIFIED TYPICAL GENERIC DATA LINK data links has not identified any totally duplicate on-going data link programs that should be terminated at this time. One reason for this situation is that certain data links have been specialized by incorporating processing functions more naturally associated with the source and sink subsystem within the data link itself. This specialization renders the link difficult to incorporate in other applications. Certain near-term data link programs have been identified as candidates for consolidation with other current data link programs (see Table S-1). In addition to these possible consolidations, it appears that a limited amount of interoperability between the PLRS and JTIDS is achievable.

Table S-1. CANDIDATE NEAR-TERM DATA LINKS FOR CONSOLIDATION WITH CURRENT DATA LINKS

Candidate Data Links	Current Data Links
1. SOTAS Imagery	AIDATS CEFLY LANCER wide band ICNS wide band COMPASS BRIGHT
2. PLSS Command	JTIDS
3. PLSS GB Guidance	WCCM narrow band PMACS narrow band ICNS narrow band
4. PLSS Sensor	AIDATS CEFLY LANCER wide band ICNS wide band COMPASS BRIGHT
5. RMCS Command	JTIDS WCCM narrow band PMACS narrow band ICNS narrow band
6. RMCS Wide Band	AIDATS CEFLY LANCER wide band ICNS wide band COMPASS BRIGHT
7. NOS	AIDATS CEFLY LANCER wide band ICNS wide band COMPASS BRIGHT
8. GBU-15 Command	Walleye II narrow band

No near-term data link programs have been identified as candidates for the development of F^3 specifications. However, two far-term data link programs that are in an early development phase and appear to have possible wide applications are the Integrated Communications Navigation System (ICNS) and the Tactical Reconnaissance Data Link (TRDL). Although the ICNS is currently designed as an integrated package, it is ARINC Research Corporation's understanding that the link is being redesigned to facilitate implementation on a modular basis. Application of F^3 specifications to both these systems should be considered.

3.4 Evaluation of Future Data Link Developments

The data link concept for all new developmental systems should provide for using an existing data link (MIL-qualified) if such use can be accomplished without adverse impact on the system. If an unmodified existing data link cannot be practically incorporated into a newly developed system, a modified existing data link should be considered. If it has been determined that no existing data link, modified or unmodified, can meet the requirements of a new developmental system, a new data link (partial or complete) will be required. If the new link must be developed in the near-term (less than 4 years), F^3 characteristics should be prepared for the basic data link interface and for all data link LRUs. The generic data link architecture would be used as guidance in defining the extended data link interface. If standardization cannot be achieved at the basic interface, a unique data link must be developed.

The standardization of a far-term data link should be implemented by the development of F^3 characteristics for all LRUs within the extended data link, in accordance with the appropriate generic data link block diagram.

3.5 Economic Impact of Standardization

The overall results of the economic analysis indicate that generic data links could result in substantial life-cycle-cost savings over the procurement of one-of-a-kind and limited quantities of distinct specialized data links.

The wide band data link family was selected for the analysis because of its current high interest to DoD and the availability of development and production cost and production quantity information on the data links within that family. The constituent cost elements of the three major cost categories (RDT&E, Investment, and Operation and Support) were analyzed to determine the elements that contributed the most to the cost savings that could be realized by a wide band generic data link. The three cost elements that contributed the most to the estimated cost savings ($170M) of the generic data link were the RDT&E, initial spares procurement, and the holding costs. The RDT&E cost saving was $69.8M (41 percent of the total savings), initial spares procurement was $26.4M (15.5 percent of the total savings), and the holding cost was $33.6M (19.7 percent of the total savings). Also, a sensitivity analysis was performed on the wide band generic data link to determine the sensitivity of the results obtained to variations of values of the system MTBF and the unit cost. The sensitivity analysis showed that the potential economic advantage of the generic data link is generally insensitive to variations to the estimated MTBF and the unit cost of the generic link over a comparatively wide range (approximately 4:1 for the MTBF and slightly less than 2:1 for the unit cost).

Figure S-4 shows that in all of the major cost categories the LCC of the generic data link is less than the LCC of the sum of the wide band data links considered in this study.

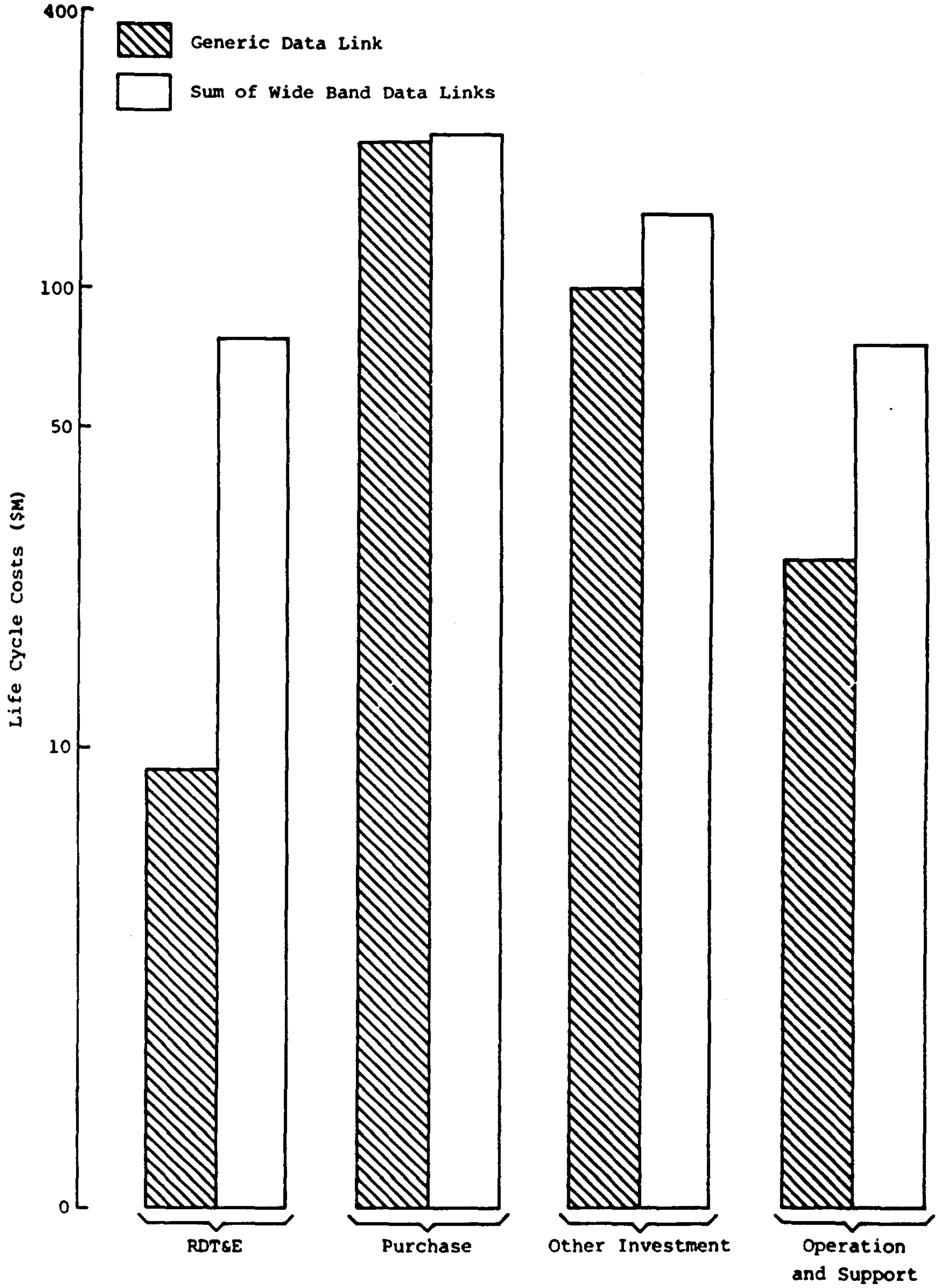


Figure S-4. LIFE CYCLE COST VS SELECTED COST ELEMENTS

4. CONCLUSIONS AND RECOMMENDATIONS

The major conclusions and recommendations of the study are presented in the following paragraphs.

The main conclusions of the study are:

- Data Links have not been recognized as a significant category of electronic equipment.
- The data links considered in this study can be categorized into six modular growth generic data links (HF, Low Data Rate, TDMA/Multiple User, Wide Band, Integrated Sensor, and Electro-Optical).
- A near-term approach is required to reduce data link proliferation by consolidating near-term programs and imposing the requirement that every effort be made to utilize existing data links to meet new requirements. Certain near-term data link programs were identified as candidates for consolidation.
- A far-term approach is required for data link standardization to allow sufficient time to initiate the development of F^3 characteristics that could be applied to many of the generic data links or their LRUs.
- No current data link programs have been identified as totally duplicative and subject to termination.
- No near-term data link programs have been identified for the development of F^3 characteristics. However, a parallel program of data link hardware and F^3 characteristic development could be initiated to shorten the time period required to produce a data link to F^3 characteristics.
- Two far-term data link programs (ICNS and TRDL) have been identified as possible candidates for the development of F^3 characteristics.
- The overall results of the economic analysis indicate that generic data links could result in substantial life-cycle-cost savings over the corresponding non-standard data links.
- No organization exists with the authority to control the development and acquisition of data links.

The major recommendations of the study are:

- Data links should be recognized as a significant category of electronic equipment.
- The concept of generic modular growth data links should be implemented to standardize future data links.
- F^3 characteristics should be developed on the ICNS or TRDL program as the initial step in evolving a standard data link family.
- Detailed examination should be conducted of the potential candidate data links for consolidation to determine if such consolidation can be implemented.

- An investigation should be initiated to examine possible standardization at the module level within the LRUs of the generic data links.
- An executive agent should be chartered to act as the focal point for the development and acquisition of all DoD data links. The executive agent should have the authority to conduct necessary detailed investigations of the recommended near-term data link program consolidations and to plan and implement far-term data link standardization.
- Cost goals and program milestones for data links associated with major weapon systems should be established and monitored independently of the weapon systems.
- The potential requirement for limited interoperability between JTIDS and PLRS should be investigated.
- An investigation should be initiated to evaluate the possibility of implementing a standard partitioning of processor functions between the data link and source/link subsystems.
- The LCCM should be used to evaluate the life-cycle costs of other data link families and refine the life-cycle-cost analyses as more accurate cost data becomes available.
- A pilot program to develop a generic data link in the near term should be initiated.

CONTENTS

CONTENTS (continued)

CONTENTS (continued)

CHAPTER ONE

INTRODUCTION

This report presents the results of a study of tactical data links used by the Department of Defense (DoD). A discussion of the background of the study, the contract objectives, the project scope, and the organization of this report is presented in this chapter.

1.1 BACKGROUND

There is increasing emphasis throughout the Department of Defense on reducing the excessive proliferation of data link programs. In August 1974, the DoD Data Link Planning Committee, with representation from all of the Services and Defense Agencies, was organized to examine and act on suspected unwarranted duplication among data link programs, lack of standardization and interoperability among data link programs, lack of suitable data link quantitative measures, lack of data and criteria to provide the basis for DoD-wide management decisions, and lack of suitable definitions for data links versus communications and navigation links.

The DoD Data Link Planning Committee was chartered to conduct a comprehensive review, analysis, and evaluation of virtually all DoD data link programs and projects. The end objective of the review was the elimination of unwarranted duplication of effort and determination of how best to maximize the cost effectiveness of those projects which are deemed suitable for continuation.

The Committee considered a number of tasks in its deliberations, including:

- Review and catalog all present and planned DoD data link efforts.
- Investigate whether unwarranted duplication exists among the DoD data link programs.
- Determine if any mission areas lack adequate data link support.
- Recommend to the Director of Defense Research and Engineering (DDR&E), the Assistant Secretary of Defense Intelligance (ASDI), or the Assistant Secretary of Defense Installation and Logistics (ASDI&L) the data link programs that should be continued, modified, merged, or terminated.

- Prepare a plan for Research, Development, Test and Engineering (RDT&E) and production of DoD data links.
- Develop a management mechanism for continued review and analysis of on-going and new data link programs.

The Committee observed that a major cause of the duplication is the individual system managers who have responsibility for data link development, who tailor data links to their precise need, and who have no incentive for coordination with other system managers or use of existing links. The Committee concluded that there was a need to formalize the data link review process, establish standards, and investigate the "black box" approach to data links. They recommended that a moratorium be declared on all new developments or changes in the status of links now in development. They also recommended that the Committee be chartered to review all new data link development and production projects and recommend action to the DSARC/DDR&E/ASD(I)/DTACCS. The Services and Agencies would have the option to reclama through the Committee.

The problems which caused the Committee to be formed were also expected to make it difficult for the Committee to successfully carry out its charter; e.g., each Service or Defense Agency tends to claim a unique mission area (electromagnetic environment, physical packaging requirement, etc.) and uses this as a basis for not employing an existing data link. The Service and Defense Agency attitude was warranted in some cases because the available systems (with a few exceptions) were custom tailored to meet particular mission envelopes. Much of the problem was the result of too little overview of data links in the past when interoperability and cost were not emphasized as they are today. Thus, to determine logically which of the current and planned data link programs should be continued, modified, merged, or terminated, it was necessary to characterize each system's basic measures, including information transfer, environmental factors, performance, and effectiveness. These measures are the parameters used to determine the degree of existing duplication and the degree of standardization possible. Once the extent of the duplication and standardization are determined, new or modified data link programs can be defined. The ultimate feasibility of a new or modified program should be based on a comparative cost and suitability evaluation of the candidate data link standardization programs.

In view of the magnitude and nature of the problems, the DoD Data Link Planning Committee contracted with ARINC Research Corporation for engineering services to review and analyze the data link program. Other general purposes of the consulting work were to contribute to informed decisions on the identification and development of a standard family of cost-effective systems, and make available ARINC Research experience in investigating the feasibility of developing future data link systems using Form, Fit, Function (F^3) specifications to enhance interchangeability.

1.2 CONTRACT OBJECTIVES

The prime objective of the contract effort was to provide engineering support to the DoD Data Link Planning Committee in their effort to accomplish a review of virtually all DoD data links in development or undergoing procurement. Specific objectives were to:

- Define a minimum set of candidate standard data links which satisfy most current and future requirements.
- Compare the existing data link development programs with the defined standard data link set and with each other to identify possible duplicative programs. Recommend possible management and design actions that could reduce the proliferation of data links and enhance the transition to the standard data links.
- Investigate the applicability of F^3 specifications to procurement of data links.
- Identify and assess the economic impact of data link standardization.
- Conduct special studies, analyses, and investigations as assigned.

Several special analyses have been performed for DDR&E. Results of these analyses, submitted under separate cover, were based on the information accumulated for the basic study and include the following:

- Jamming vulnerability analysis of the Walleye and GBU-15 systems (March 1976)
- Review and analysis of Army's Miniature RPV Aquila Data Link (June 1976)
- Review and analysis of "Final Report, Data Link Consolidation Task" (October 1976)
- Review of AN/GRA-114 (January 1977)

1.3 PROJECT SCOPE

The scope of the ARINC Research effort was limited to an investigation and analysis of tactical data links currently under development and future data links that have a definite stated requirement. Excluded from the study were the following:

- Operational systems
- Systems undergoing phaseout
- Fixed-facility, long-distance, point-to-point communications under the purview of the Director, Telecommunications and Command and Control Systems

* Acoustic links
* Any links utilizing transmission lines

As the study progressed, other scope limitations were identified, primarily as a result of the nature of the available data. These additional limitations are discussed in subsequent chapters of this report.

1.4 REPORT ORGANIZATION

The methodology employed and the results obtained in the ARINC Research study are presented in the three following chapters.

Chapter Two describes the approach that was used to develop the standard data link families to assess the potential for data link standardization, and to analyze the economic impact of such standardization.

Chapter Three presents the results of the study and evaluates them in relation to prospective short-range and long-range actions. Short-range measures would be directed toward reduction of data link proliferation by means of termination or consolidation of specific programs; long-term actions would provide the basis for data link standardization.

Chapter Four summarizes the study's major conclusions and recommendations related to the near-term and far-term objectives.

A description of the analysis approach used in the study, with an example illustrating the process, is given in Appendix A. Appendix B lists the documents used and other sources from which information was sought.

Appendixes, C and D present, respectively, the abbreviations and acronynms used in the report, and a glossary of terms. Appendix E presents the input data parameters used in the economic impact analysis.

CHAPTER TWO

ANALYSIS APPROACH

This chapter presents an overview of the analysis approach used in the investigation of the DoD data links. It is divided into three main subject areas: (1) the methodology for developing data link families, (2) the data link standardization assessment process, and (3) the analysis of the economic impact of standardization.

Because of the manner in which the methodology evolved throughout the study, the results obtained in each major area are presented with the analysis. The details of the analysis approach and its development are presented in Appendix A.

2.1 METHODOLOGY FOR DEVELOPING STANDARD DATA LINK FAMILIES

2.1.1 Overview

The methodology encompassed five principal steps:

1. Defining the study ground rules and data base requirements
2. Acquiring the data base
3. Defining a minimum set of data link descriptors
4. Establishing data link families and descriptor matrices
5. Developing the characteristics of the data link families

The interrelationship of these steps is illustrated in Figure 2-1.

2.1.2 Ground Rules

Study ground rules were developed in coordination with the DoD Steering Group to arrive at a common understanding of the assumptions, boundaries, and limitations of the ARINC Research study effort. The Steering Group, comprising representatives from DDR&E and the military services, was formed to provide direction and guidance to the study effort.

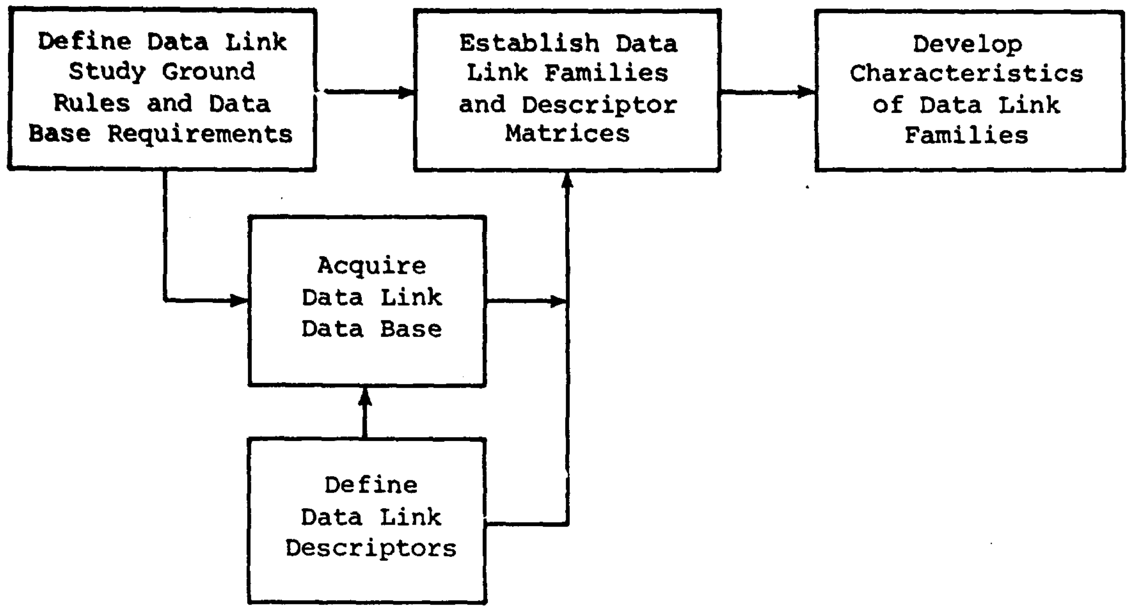


Figure 2-1. METHODOLOGY FOR DEVELOPING STANDARD DATA LINK FAMILIES

The primary ground rules of the study were (1) the definition of a data link and the general breakdown of the equipments that make up a data link, (2) the limitation of the study to data links under development, (3) the description of categories of data links that were excluded from the study, and (4) the initial treatment of all data links under study as simplex links.

It was necessary to define a data link so that the study would be limited to that portion of a complete system concerned with the transmission of data, not the formation or utilization of the data. To this end, the following general definition was developed and coordinated with the Steering Group members:

> "A data link is defined as that portion of a system that provides transfer of formatted information between an information source and an information sink."

A block diagram of a typical data link is shown in Figure 2-2. The major elements constituting the data link are the receiving and transmission subsystem and the signal conditioner/reconditioner subsystem. The data link receives information from an information source and delivers it to an information sink.

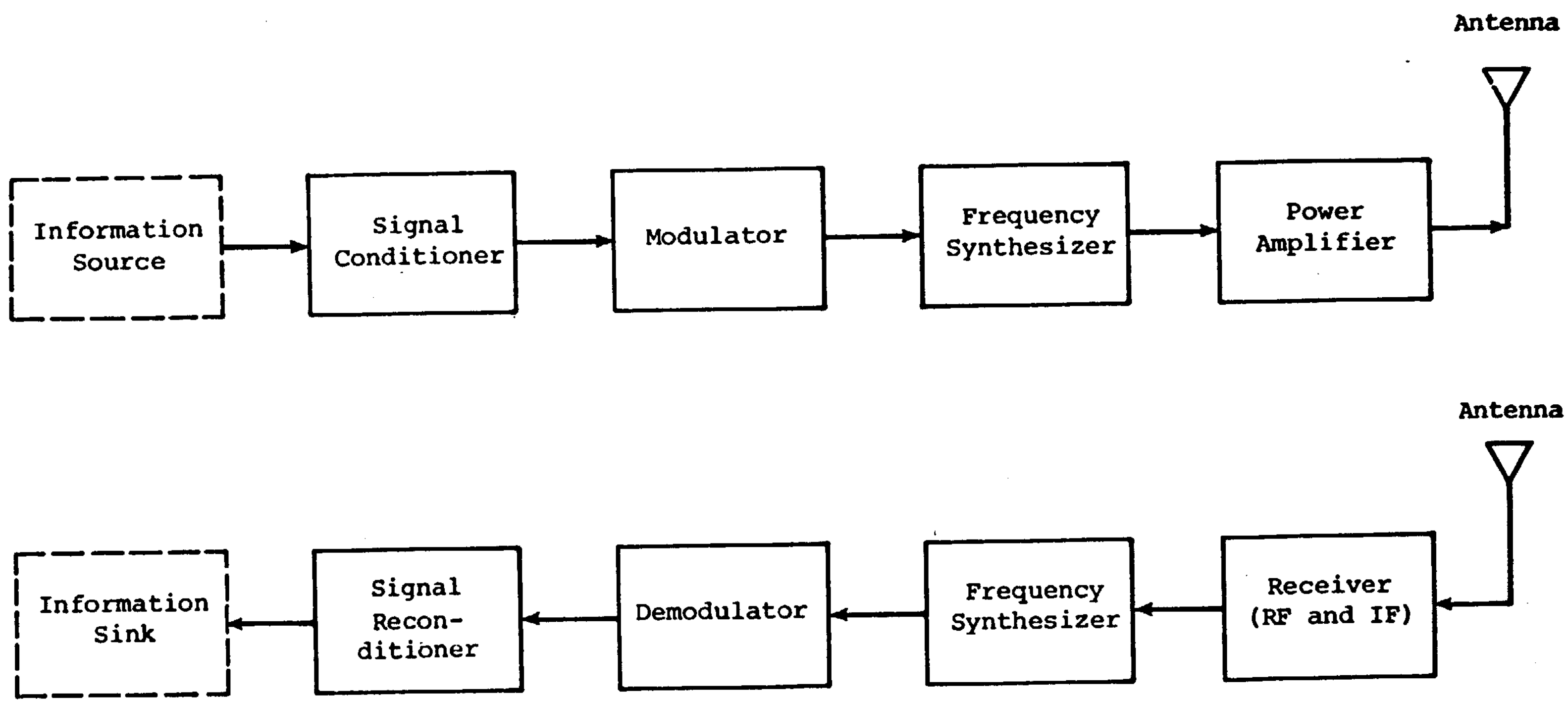


Figure 2-2. BLOCK DIAGRAM OF A TYPICAL DATA LINK

The second ground rule was to limit the study effort to data links under development. If any standardization was to be obtained, there would be no reason to include data links which were already operational or for which future use was so distant that their requirements were undefined. Further definition of data links under development was necessary to establish a basis for the data link families. Data links that were in production (P), undergoing test and evaluation (T), or in the final stages of engineering development (ED) were classified as "current systems". Because their parameters and characteristics were defined, these data links would be used in the initial development of the data link families. Systems in exploratory development (EXP), advanced development (AD), concept formulation (C), or engineering development (with the exception of the final stage) were classified as "future systems". These systems would be used to refine the characteristics of the data link families initially defined on the basis of the current links.

In their review of DoD data link programs, the DoD Data Link Planning Committee excluded the fixed-facility, long-distance, point-to-point communications under the purview of the Director, Telecommunications and Command and Control Systems; acoustic communications; and any communications that utilize transmission lines. These exclusions were maintained in this study. Operational systems and systems being phased out were also excluded from the study.

To permit developing the basic descriptors of the data links without being inhibited by the complexity of data links that transfer more than one type of information (e.g., Command and Control, status, video), it was decided to treat each information-transfer function as a separate link during the family development process.

In addition to the primary ground rules, more restrictive ground rules were developed during the study. These are documented in the discussion of specific areas.

2.1.3 Description of Data Base

The data base consists of technical descriptions of the current and future data link systems involved in the study. These descriptions furnished the basic information from which a review could be conducted to evaluate the apparent proliferation of data links, to group the data links into categories to allow the possible reduction in the quantity of data links, and to develop a minimum number of "standard" data links that could eventually provide the basis for long-term standardization.

In addition to the technical descriptions of the data links, data on development and acquisition cost and quantity were gathered to permit an analysis of the economic impact of implementing standard data links.

The data base was obtained from 34 current systems consisting of 66 data links and 17 future systems consisting of 34 data links. The major information sources from which the data links and their descriptors were obtained are as follows:

- Data Link Planning Committee notebooks
- Supplementary technical and cost information from the military services and data link contractors
- Documents provided by the Defense Documentation Center (DDC)
- Computer listings of systems with data links from the Electromagnetic Compatibility Analysis Center (ECAC)

Appendix B lists the source documents used in this study.

2.1.4 Descriptor Selection

There is an abundance of parameters or descriptors that can be used to describe data links. To avoid overcomplexity from using too many descriptors and oversimplification from using too few, a methodology was developed for obtaining a manageable quantity of descriptors. This minimum set would permit categorization or grouping of data links with identical or similar descriptors. The groupings could be analyzed to develop the characteristics of the "standard" data links. The descriptors would also provide a means of comparing the major technical characteristics of the data links to determine duplications and near-duplications.

The methodology developed to obtain a minimum set of descriptors consisted of (1) preparing a comprehensive list of all data link descriptors; (2) defining criteria by which a minimum set of descriptors was to be selected; (3) applying the criteria to the list of descriptors and selecting the minimum descriptors set; and (4) defining the quantitative measure, scale, and units for the selected descriptors.

The list of 53 candidate descriptors from which the minimum set was to be selected consisted of four types: (1) performance characteristics, (2) environmental characteristics, (3) technical and physical characteristics, and (4) information structure. Development of the entire set of descriptors was based on review of the available information from the Steering Group and on consultation with knowledgeable personnel within ARINC Research and data link manufacturers.

The next effort was to define criteria by which the candidate list of descriptors would be evaluated to obtain the minimum set of descriptors necessary to describe each of the data links adequately. Five criteria were defined:

1. The descriptor had to be quantifiable. Relative values (such as many, few, high, low) would be avoided.
2. The descriptor had to be capable of being related to the system requirements.

3. The descriptor had to vary unambiguously with the system requirements.

4. The selected descriptors had to be independent. For example, frequency band does not require any further description; it is independent of the other descriptors.

5. The descriptor had to be applicable to and consistent with prior definitions.

The criteria were applied to the list of 53 descriptors. From this overall list, 10 descriptors were selected as meeting the criteria. Table 2-1 lists the selected descriptors, together with the scale and units to be used. The selected descriptor list contained data on the type of signal, information bandwidth of the signal, frequency band of the carrier, number of users, range of the data link, platforms on which the data links were located, and security provisions of the data link (LPI, AJ Margin, encryption).

Table 2-1. SELECTED DESCRIPTORS

Descriptor	Measure
Type	Signal Type (e.g., Analog or Digital)
Information Bandwidth	kHz
Anti-Jam Margin	Jam-to-Signal Ratio (dB)
Intercept Probability Measure	Beam Width (Degrees) × Output Power (watts) ÷ RF Bandwidth (kHz)
Encryption	Yes or No
Frequency Spectrum	Alphabet-Designated Band
Range	Kilometers
From Unit	Ranked by Type of Operational Environment
To Unit	Ranked by Type of Operational Environment
Number of Users	Number of Channels × Users per Channel

The Intercept Probability Measure descriptor was developed to evaluate the low probability of intercept (LPI) characteristics of the data links. The LPI of any data link system is directly dependent on the scenario, EW threat, and the data link capability. The data link capability is, together with other parameters, directly dependent on the RF power and antenna beamwidth and inversely dependent on the RF bandwidth. The ratio of the product of the RF power and antenna beamwidth to the RF bandwidth was designated the Intercept Probability Measure. It is a figure-of-merit for intercept probability characteristics that permits a relative comparison in the dimension of different data links.

Each of the data links considered in this study was quantified in terms of the minimum set of descriptors for subsequent development of the data link families.

2.1.5 Data Link Family Development

This section addresses (1) the development of a minimum set of data links that satisfy most present requirements, (2) the incorporation of future data links into the developed minimum set in order to satisfy most present and future requirements, and (3) the refinement and consolidation of the developed data link families. Figure 2-3 illustrates this process. Each of the steps in the development process is described in the following subsections.

2.1.5.1 Development of a Minimum Set of Data Links

The objective was to restructure the 66 current discrete data links into a smaller set in which each element represented a grouping of links (in some cases, one link) from the original data base.

The approach used to develop the minimum set of data links consisted of six steps.

Step 1: Separate the Data Base into Current and Future Data Links

The current links were used as the basic elements in the development of the data links; the future links would be added later to expand the coverage of the minimum set of data links.

Step 2: Perform Initial Partitionings of the Current Data Links

By an iterative process, a minimum number of descriptors were used to categorize the data links into distinct partitions. Several different types of partitioning were attempted to permit eventual consolidation of the links into separate and distinct families. The data links were partitioned first by type, information bandwidth, data rate, and range; and second by information bandwidth, transmitter power, and AJ margin. The descriptors finally selected for the first partitioning were RF transmitter power and information bandwidths. RF power was separated into three categories: Low Power (LP), $<$10W; Medium Power (MP), $\geq$10W$\leq$100W; and High Power (HP), $>$100W. The Information Bandwidth was also separated into three categories: Narrow Bandwidth (NB), $<$50kHz; Medium Bandwidth (MB), $\geq$50kHz$\leq$5MHz; and Wide Bandwidth (WB), $>$5MHz. Combinations of these two descriptors, power and bandwidth, resulted in nine "bins" or "filters", which segregated the 66 current data links into nine partitions.

Step 3: Characterize the Data Links within Each Partition

Each of the data links within each of the partitions was described according to the minimum set of selected descriptors. These descriptors provided the basis for subsequent groupings of the data links.

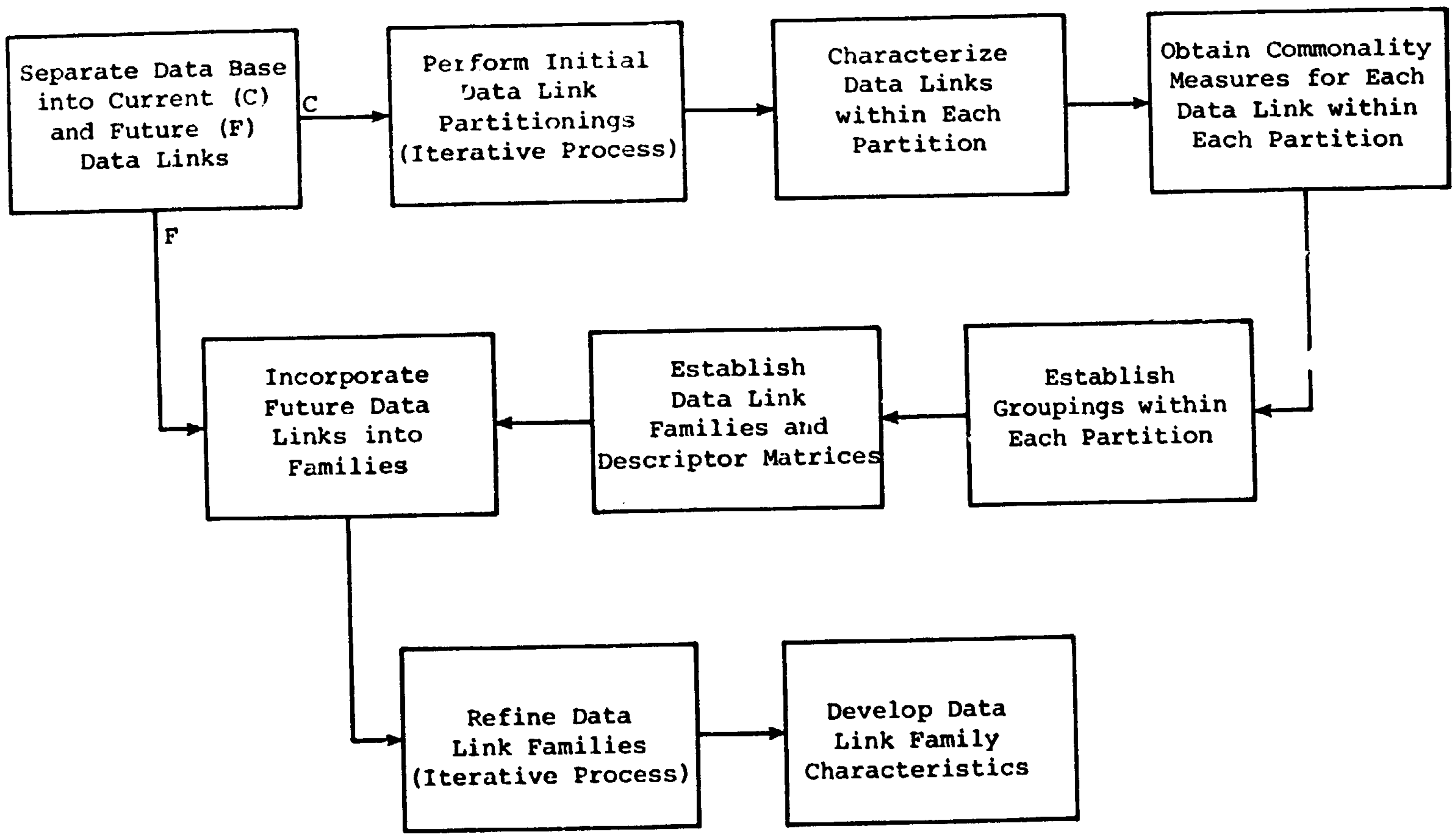


Figure 2-3. DEVELOPMENT OF DATA LINK FAMILIES

Step 4: Obtain Commonality Measures for Each Data Link within Each Partition

The purpose of the commonality analysis was to identify systems with a high commonality index that could be used as the basis for developing a data link family. The output of the analysis was a listing of all data links within a partition, together with their descriptors, and a commonality matrix for comparing the descriptors of each data link within a partition with all other data links within the partition. The commonality measures for each data link were evaluated by using a time-share computer to facilitate the computations. The criteria applied to assess the commonality of the data links within each of the partitions are listed in Table 2-2. The main criterion was downward compatibility; for example, the range of the compared system had to be equal to or less than the reference system.

Table 2-2. COMMONALITY ASSESSMENT CRITERIA

Descriptor	Criterion*
Type (T)	$T_i = T_j$
Information Bandwidth (B)	$B_i \geq B_j$
Anti-Jam Capability (AJ)	$AJ_i \geq AJ_j$
Intercept Probability (I)	$I_i \leq I_j$
Encryption (E)	$E_i \geq E_j$
Frequency Spectrum (F)	$F_i = F_j$
Range (R)	$R_i \geq R_j$
From Unit (FU)	$FU_i \geq FU_j$
To Unit (TU)	$TU_i \geq TU_j$
Number of Users (N)	$N_i \geq N_j$

*i = reference system; j = compared system.

The resulting commonality matrix is shown in Figure 2-4. This matrix consists of 12 columns; the first column lists the data links within a partition; the next ten columns list the descriptors associated with the respective data links; and the last column is the average overall descriptor percentage for the reference system. The rows of the matrix list all of the data links within a partition and the average commonality index associated with each descriptor. The last row is the average over all systems of the descriptor commonality index. For example, if data link system 2 was used

Data Link System	Descriptors A B C D E F G H I J	Average Data Link Commonality
1		
2	0.867	0.452
3		
•		
•	Percent of all other systems within partition that could be satisfied by descriptor capability of reference system.	Average over all descriptor percentages for reference system.
•		
•		
•		
•		
N		
Average Descriptor Commonality	0.237	Average, over all systems, of descriptor commonality percentages.

Figure 2-4. COMMONALITY MATRIX

as the reference system and compared with all of the remaining data links within the partition, the following information would be obtained:

- Descriptor C could satisfy 86.7 percent of all other systems within the partion.
- Data link system 2 has 45.2 percent descriptor commonality with all of the compared systems.

In addition, the last line of the matrix indicates the average, over all systems, of descriptor commonality. For example, the average, over all systems, of descriptor C is 23.7 percent.

Step 5: Establish Groupings within Each Partition

Specific groupings of data links within each of the partitions were developed by use of the commonality matrix and the descriptor matrix. Analysis of the commonality matrix made it possible to evaluate data link commonality as the first step in the grouping process. Examination of the average data link commonality column permitted the initial groupings of data links with identical or nearly identical indexes. The index associated with each of the ten descriptors of each of the data links was examined further to assess possible areas of incompatibility between the data links contained in the preliminary groupings. The descriptor matrix was then analyzed to identify (1) unique features of data links within the partition, (2) incompatible information bandwidths, (3) AJ and crypto requirements, and (4) platform locations. Combined analysis of these two matrices permitted refinement of the initial partitioning effort. The grouping analysis resulted in a potential consolidation of the original 66 data links into 27 groups. Initial groupings of the original 66 data links are illustrated in Figure 2-5; an example of the grouping process using the commonality matrix and the descriptor matrix is shown in Appendix A.

Step 6: Establish Data Link Families and Descriptor Matrices

To further consolidate the 27 groups of data links into a smaller set of groups called families, criteria were developed to relax the constraints imposed on the initial groupings. The criteria involved eight of the descriptors. The overall approach was to permit downward compatibility of data links; e.g., if one of the constraints against consolidation of certain data links were the difference in RF power requirements while the other descriptors were common, the downward criterion allowed a lower RF power data link to be grouped with data links with a greater RF power requirement. The downward compatibility criteria was also applied for security, users per channel, and packaging. The information bandwidth requirement was relaxed to permit consolidation of data links with a 10 to 1 compatibility ratio. This consolidation used two design approaches: Modular Growth Design and Modular Family Design. The Modular Growth Design approach employed a basic standard module to which other modules could be added to increase capability; for example, by adding a power amplifier. In the Modular Family Design approach a basic capability was modified by substitution of elements within a module, such as a new RF section to allow coverage of a different frequency band. The grouping criteria and design approaches are shown in Figure 2-6.

Application of the inter-partition grouping criteria to the 27 groupings resulted in a further consolidation of the data links into nine groupings or families: two were analog systems; one consisted of the satellite links; two were microwave sensor systems; two were microwave command and control systems; and two were command and control systems in the VHF/UHF frequency spectrum. Figure 2-7 lists the families and the data links included in each.

The Data Link Family Descriptor Matrices were then developed from analysis of the descriptors of the data links in each family. The resultant matrix, shown in Figure 2-8, consisted of descriptor values that were the limiting values of those obtained from the data links within each family.

This step resulted in the initial set of data link families that may satisfy all of the requirements of the current data links.

2.1.5.2 Incorporation of Future Data Links

Forty-one future data links were identified. However, five of the future data links were not included in this study because the programs are feasibility investigations that do not now have an associated defined data link (Teal Feather, Teal Wren, Teal Wing, OPSATCOM, and OCCULT). In

LP/NB				MP/NB					HP/NB		
A	B	C	D	E	F	G	H	I	J	K	L
GRA-114 (Sound) GRA-114 (CMD) PEWS Dnl.	AMQ-23	TACFIRE FO-FDC	AGTELIS OS-CP	AFSATCOM Uplk AFSATCOM Dnlk FLTSATCOM Uplk FLTSATCOM Dnlk	AGTELIS CP to MULTEWS (G) COMPASS EARS TPQ-36 TPQ-37 TSQ-73 ASAP Survivor MULTEWS (G-G) Uplk MULTEWS (G-A) Uplk SAM-D Inter SAM-D Intra TACFIRE FDC-BDU	JTIDS AGTELIS CPC to CAC AGTELIS CP to CPC CEFLY LANCER (NB) Uplk CEFLY LANCER (NB) Dnlk QUICKLOOK II TACELIS Uplk TACELIS Dnlk COMPASS BRIGHT Uplk	CONDOR CMD MGGB/EOGB CMD WALLEYE (D) CMD JSOR CMD	PLRS Manpack PLRS A/C	SETAD	CEFIRM LDR Uplk	PLSS Control

LP/MB		MP/MB			HP/MB
M	M	O	P	Q	R
LEFOX GREY (MCA) Uplk TACELIS CPC-RMS Uplk	LAMPS III CMD Dnlk	TACJAM (RMS-TJ) Uplk TACJAM (RMS-TJ) Dnlk	AGTELIS (CP to ALQ-133) Uplk AGTELIS (CP to ALQ-133) Dnlk	LAMPS III (CMD) Uplk	CEFLY LANCER (WB) Uplk LEFOX GREY (ACA) Uplk

LP/WB		MP/WB			HP/WB			
S	T	U	V	W	X	Y	Z	AA
LAFAIRE VITE Uplk LAFAIRE VITE Dnlk	LEFOX GREY (MCA) Dnlk TACELIS (CP to RMS) Dnlk	CONDOR Video JSOR Video WALLEYE Video MGGB/EOGB Video	LAMPS III (Acoustic) ASW	LAMPS III (Radar) ASMD	AIDATS Dnlk UPD-X	QSR (IR)	LEFOX GREY (ACA) CELFY LANCER (WB) Dnlk COMPASS BRIGHT Dnlk	PLSS Sensor

Figure 2-5. INTRA-PARTITION GROUPING

Descriptor Factor	Criterion	Design Approach
Information Bandwidth	10:1 Compatibility Ratio	Modular Growth Design
Frequency Band		
Below 200 MHz	Bands compatible	Unique Design
Above 200 MHz	Bands use common IF	Modular Family Design
Power/Range	Downward Compatible	Modular Growth Design
Security	Downward Compatible	Modular Growth Design
Users per Channel	Downward Compatible	Modular Growth Design
Packaging	Downward Compatible	Modular Family Design
Signal Type	Match	Unique Design

Figure 2-6. INTER-PARTITION GROUPING CRITERIA

addition, two data links -- TEREC and TASES -- were excluded because they will use existing links. Thus, 34 future data links were added to the data base and the datalinks families were refined.

The addition of the future data links resulted in several changes to the existing data link families. Two new data link families were added (HF and EO) and two of the families were deleted. The wide band analog sensor family that contained only the LAMPS III (ASMD) link was deleted because it is being designed as a digital link, which is included in the wide band microwave sensor family. The very wide band analog sensor family that contained only the QSR (IR) link was deleted as a separate family and included in the wide band microwave sensor family. The inclusion of the QSR (IR) in the wide band sensor family was based on the assumption that future data links would be digital and that band width compression would be utilized. The characteristics of the other families did not change, although it was necessary to change number designations, as summarized in Figure 2-9.

In the revised composition of data link families shown in Figure 2-10, the future data links in Families II through VII are shown below the horizontal lines in each column.

Incorporation of the future data links resulted in eleven changes to the Data Link Families Descriptor Matrix, as shown in the revised descriptor matrix (Figure 2-11).

CHARACTERISTIC	WIDE BAND ANALOG SENSOR	VERY WIDE BAND ANALOG SENSOR	UHF BAND COMPOSITE SATELLITE	NARROW BAND VHF/UHF COMMAND & CONTROL	MEDIUM BAND VHF/UHF COMMAND & CONTROL	NARROW BAND MICROWAVE COMMAND & CONTROL	MEDIUM BAND MICROWAVE COMMAND & CONTROL	WIDE BAND MICROWAVE SENSOR	VERY WIDE BAND MICROWAVE SENSOR
FAMILY / DATA LINKS	I	II	III	IV	V	VI	VII	VIII	IX
	LAMPS III (ASMD)	QSR (IR)	AFSATCOM Up AFSATCOM Dn FLTSATCOM Up FLTSATCOM Dn	AGTELIS (CP to MULTEWS) AGTELIS (CPC to CAC) AGTELIS (CP to CPC) AGTELIS (OS to CP) ASAP-Survivor AN/TPQ-36 AN/TPQ-37 CEFLY LANCER (NB) Up CEFLY LANCER (NB) Dn GRA-114 (Sound) GRA-114 (CMD) PEWS (Dnlk) QUICKLOOK II MULTEWS (G-G) MULTEWS (G-A) TACELIS (RMS-RS) Up TACELIS (RMS-RS) Dn TACFIRE (FO-FDC) TACFIRE (FDC-BDU) SAM-D (Intra) SETAD Dn	AGTELIS (CPC to ALQ-133) Up AGTELIS (CPC to ALQ-133) Dn	AMQ-23 AN/TSQ-73 CEFIRM LDR (Up) COMPASS BRIGHT Up COMPASS EARS JTIDS PLSS (Control) PLRS (Manpack) PLRS (A/C) SAM-D (Inter) CONDOR (CMD) JSOR (CMD) WALLEYE (CMD) MGGB/EOGB (CMD)	CEFLY LANCER (WB) Up LEFOX GREY (ACA) Up LEFOX GREY (MCA) UP LAMPS III (CMD) Up LAMPS III (CMD) Dn PELSS SENSOR TACELIS (CPC to RMS) Up TACJAM (RMS-TJ) Up TACJAM (RMS-TJ) Dn	CEFLY LANCER (WB) Dn LAFAIRE VITE Up LEFOX GREY (MCA) Dn LAMPS III ASW TACELIS (CPC to RMS) Dn CONDOR Video JSOR Video WALLEYE Video MGGB/EOGB Video	AIIATS COMPASS BRIGHT Dn LAFAIRE VITE Dn LEFOX GREY (ACA) Dn UPD-X
TOTALS	1	1	4	21	2	14	9	9	5

Figure 2-7. INTER-PARTITION GROUPING

Data Link Family	Descriptor									
	Type	Information Bandwidth (KHz)	Anti-Jam* (dB)	PI**	Crypto	Freq. Band Range	Range (KM)	From (Platform)	To (Platform)	Number of Users Per Channel
I	Analog	3000	None	461	No	4-6G	37	Aircraft	Ship, Surf.	1
II	Analog	50,000	None	17	No	10-20G	556	Aircraft	Gnd. Trans.	1
III	Digital	10	25	2400	Yes	UHF	556	Aircraft	Satellite	50
IV	Digital	18	20	1	Yes	UHF	556	Aircraft	Aircraft	24
V	Digital	100	20	211	Yes	UHF	122	Aircraft	Aircraft	1
VI	Digital	48	30	29	Yes	1-20G	556	Aircraft	Missile	1000
VII	Digital	1200	None	1	Yes	1-20G	556	Aircraft	Aircraft	6
VIII	Digital	6250	None	1	Yes	1-20G	370	Missile	Aircraft	96
IX	Digital	50,000	50	1	Yes	8-20G	370	Aircraft	Gnd. Trans.	1

*Specifies the upper limit of the AJ protection for that family.
**Probability of Intercept Index.

Figure 2-8. DATA LINK FAMILIES DESCRIPTOR MATRIX

Data Link Family Structure	Data Link Refinement Rational	New Data Link Family Structure
--	New Family	I Narrow Band HF
I Wide Band Analog Sensor	Add to Family VII (Digital System)	--
II Very Wide Band Analog Sensor	Add to Family VIII (Requires A/D Conversion and BW Compression)	--
III UHF Band Composite Satellite	Changed Family Number	II
IV Narrow Band VHF/UHF C&C	- ditto -	III
V Medium Band VHF/UHF C&C	- ditto -	IV
VI Narrow Band Microwave C&C	- ditto -	V
VII Medium Band Microwave C&C	- ditto -	VI
VIII Wide Band Microwave Sensor	- ditto -	VII
IX Very Wide Band Microwave Sensor	- ditto -	VIII
--	New Family	IX E-O

Figure 2-9. RATIONALE FOR NEW DATA LINK FAMILIES RESULTING FROM INCORPORATION OF FUTURE DATA LINKS

NARROW BAND HF COMMAND & CONTROL	UHF BAND COMPOSITE SATELLITE	NARROW BAND VHF/UHF COMMAND & CONTROL	MEDIUM BAND VHF/UHF COMMAND & CONTROL	NARROW BAND MICROWAVE COMMAND & CONTROL	MEDIUM BAND MICROWAVE COMMAND & CONTROL	WIDE BAND MICROWAVE SENSOR	VERY WIDE BAND MICROWAVE SENSOR	ELECTRO-OPTICAL
I	II	III	IV	V	VI	VII	VIII	IX
SETAD-HF	AFSATCOM Up AFSATCOM Dn FLTSATCOM Up FLTSATCOM Dn SURVSATCOM Up SURVSATCOM Dn	ACTELIS (CP to MULTEWS) AGTELIS (CPC to CAC) ACTELIS (CP to CPC) AGTELIS (OS to CO) ASAP-Survivor AN/TPQ-36 AN/TPQ-37 CEFLY LANCER (NB) Up CEFLY LANCER (NB) Dn GRA-114 (CMD) PEWS (Dnlk) QUICKLOOK II MULTEWS (G-G) MULTEWS (G-A) TACELIS (RMS-RS) Up TACELIS (RMS-RS) Dn TACFIRE (FO-FDC) TACFIRE (FDC-BDU) SAM-D (Intra) SETAD Dn QUICKFIX (Up) QUICKFIX (Dn) CAC NBDS FAALS TOS ASCL-Dn REMBASS-SR REMBASS-SC (Up) REMBASS-RR (Up) REMBASS-RR (Dn) REMBASS-RC (Up)	AGTELIS (CPC to ALQ-133) Up AGTELIS (CPC to ALQ-133) Dn ASCL-Up LOSTFCS	AMQ-23 AN/TSQ-73 CEFIRM LDR (Up) COMPASS BRIGHT Up JTIDS PLSS (Control) PLRS (Manpack) PLRS (A/C) SAM-D (Inter) JSOR (CMD) WALLEYE (CMD) MGGB/EOGB (CMD) AEQUARE (G-R) (CMD) AEQUARE (R-R) (TM) AEQUARE (R-G) (TM) AEQUARE (R-R) (CMD) RMCS (G-R) CMD RMCS (R-D) CMD SEEK SKY HOOK Up SEEK SKY HOOK Dn Mini-RPV (CMD) Up Mini-RPV (STAT) Dn	CEFLY LANCER (WB) Up LEFOX GREY (ACA) Up LEFOX GREY (MCA) Up LAMPS III (CMD) Up LAMPS III (CMD) Dn PELSS SENSOR TACELIS (CPC to RMS) Up TACJAM (RMS-TJ) Up TACJAM (RMS-TJ) Dn COMPASS EARS SOTAS GUARDRAIL - Dn	LAFAIRE VITE Up LEFOX GREY (MCA) Dn LAMPS III ASW TACELIS (CPC to RMS) Dn JSOR (Video) WALLEYE (Video) MGGB/EOGB (Video) LAMPS III (ASMD) AEQUARE (R-R) (Video) AEQUARE (R-G) (Video) AQUILA (Video) Dn	AIDATS COMPASS BRIGHT Dn LAFAIRE VITE Dn LEFOX GREY (ACA) Dn CEFLY LANCER (WB) Dn UPD-X *QSR (IR) *AMCS	SACCS

* Requires A/D conversion and 3W compression

Figure 2-10. REVISED COMPOSITION OF DATA LINK FAMILIES (CURRENT AND FUTURE DATA LINKS)

Data Link Family	Descriptor									
	Type	Information Bandwidth (KHz)	Anti-Jam* (dB)	PI**	Crypto	Freq. Band Range	Range (KM)	From (Platform)	To (Platform)	Number of Users Per Channel
I	Digital	3	None	6000	Yes	HF	5556	Aircraft	Gnd. Fixed	4
II	Digital	10	90	2400	Yes	UHF	3704	Aircraft	Satellite	50
III	Digital	18	20	1	Yes	UHF	556	Aircraft	Aircraft	24
IV	Digital	100	20	4	Yes	UHF	370	Aircraft	Aircraft	8
V	Digital	48	60	29	Yes	1-20G	556	Aircraft	Missile	1000
VI	Digital	1200	60	1	Yes	1-20G	556	Aircraft	Aircraft	6
VII	Digital	6250	50	1	Yes	1-20G	370	Missile	Aircraft	96
VIII	Digital	50,000	50	1	Yes	8-20G	370	Aircraft	Gnd. Trans.	1
IX	Digital	3	None	<1	No	.5 Micron	LOS	Aircraft	Ship, Sub.	1

*Specifies the upper limit of the AJ protection for that family.
**Probability of Intercept Index

Figure 2-11. REVISED DATA LINK FAMILIES DESCRIPTOR MATRIX

2.1.5.3 Refinement of the Data Link Families

The composition of the data link families was reexamined, in coordination with the members of the DoD Steering Group, resulting in several changes to the list of data links considered in the study. The TPQ-36, TPQ-37, TSQ-73, SAM-D, TACFIRE, TOS, and CAC were excluded from further consideration because they use existing communications links. The AMQ-23, AEQUARE, CONDOR, and the Navy's universal data link (called JSOR* link) are no longer active programs and were deleted. The LEFOX GREY (ACA) was deleted because it will use the CEFLY LANCER side band data link.

Originally, all of the data links were treated as simplex links. However, during the refinement process, all the links of a specific system were grouped together and the developed data link families were reevaluated vis-a-vis potential relaxation of descriptor constraints. This was an iterative process that eventually resulted in reducing the nine data link families to six.

The reduction procedure removed the satellite data links as a separately defined data link family, retained the HF and EO families, and defined four new data link families. The four new families were (1) Low data rate, (2) TDMA/Multiple user, (3) Wide band, and (4) Integrated Expendable sensor. The Low Data Rate family contains all data links with information data rates of less than 100kbps. The TDMA/Multiple user links were isolated as a separate family because these links have unique properties to permit simultaneous exchange of information among multiple, netted subscribers. The wide band family contains all data links with information data rates of 100kbps to 100mbps. This was based on the technical feasibility of designing RF components to cover the 100kbps-100mbps range. The Integrated Expendable Sensor is a new, compact, lightweight, expendable Video/Command mini-RPV link. Possible users of this type of data are the glide bomb and stand-off missile data links.

Figure 2-12 shows the refined composition of the data link families.

2.1.6 Standard Data Link Families

As a result of the refinement effort, six data link families were developed. The following are brief descriptions of the six families:

- High Frequency (HF) - Characterized by the use of the HF band of 2-30MHz for the transmission of data. This band permits transmission beyond line-of-sight without the use of relays.
- Low data rate - Characterized by data links with information bit rates below 100kbps and no unique characteristics that would warrant assignment to one of the other families. Included in this family are links designed for a single user or a very limited number of users.

*This non-active program should not be confused with the ongoing JSOR link that will evolve from the Walleye and GBU-15 programs.

I	II	III	IV	V	VI
HF	LOW DATA RATE	TDMA/ MULTIPLE USER	WIDE BAND	INTEGRATED EXPENDABLE SENSOR	E-O
SETAD	PEWS	JTIDS	AGTELIS (to QLII)	Mini-RPV (Cmd, Stat, Video)	SAOCS
	GRA-114	PLRS	COMPASS BRIGHT (Up & Dn)	Walleye (Cmd, Video)	
	TACELIS (RMS)	LOSTFCS	LAMPS III CMD-ASW-ASMD	GBU-15 (Cmd, Video)	
	SEEKSKYHOOK		ASCL Up	PMACS	
	MULTEWS (G-A)		TACJAM	WCCM	
	REMBASS (CMD & SENSOR)		LEFOX GREY (MCA) Up & Dn		
	ASAP SURVIVOR		CFL (WB) Up & Dn		
	CFL (NB)		LAFAIRE VITE (Up & Dn)		
	QUICKLOOK II		RMCS		
	QUICKFIX		AIDATS		
	AGTELIS (to CAC)		UPDX		
	AGTELIS (to MULTEWS)		COMPASS EARS Dn		
	AGTELIS (from OUTSTAT)		GUARDRAIL Dn		
	ASCL Dn		SOTAS Dn		
			QSR (IR)		
			PLSS SENSOR		
			Seek Sky Hook		
			TDRL		

Figure 2-12. REFINED COMPOSITION OF DATA LINK FAMILIES

- TDMA/Multiple user - The prime distinguishing feature of this family is the use of time division multiple access (TMDA) architecture to accommodate a large number of users' information exchange in real time.
- Wide band - Characterized by data links with information bit rates greater than 100 kpbs and no unique characteristics that would warrant assignment to one of the other families.
- Integrated Expendable Sensor - The data links in this family have multi-functions (e.g., wide band video, command, and status) integrated into hardware that cannot be physically separated by function without extensive modification. In addition, the links are used on platforms where recovery after a mission may be impractical.
- Electro-Optical - This data link utilizes the laser technology for the transmission of data.

The characteristics of the refined data link families are shown in Figure 2-13.

2.1.7 Summary

The basic data link families presented in this subsection represent a consolidation of the numerous individual data links under development, which could provide the basis for data link standardization in the future.

2.2 DATA LINK STANDARDIZATION ASSESSMENT PROCESS

2.2.1 Overview of Methodology

In the overall methodology used to assess the potential for data link standardization, illustrated in Figure 2-14, the five main steps consisted of (1) refinement of the characteristics of the data link systems within each family, (2) development of generic data links to characterize each of the data link families, (3) evaluation of the compatibility of each data link within a family with the generic data link defined for that family, (4) evaluation of the possibility of identifying a baseline data link within each of the data link families, and (5) development of near-term and far-term data link standardization approaches. These steps are described in subsequent subsections.

2.2.2 Refinement of the Characteristics of the Data Link Systems Within Each Family

The number of descriptors associated with each data link was expanded to permit an analysis of the characteristics of the data links within each family to a greater depth than was permitted by the basic set of descriptors. The objective was to provide a basis for evaluating the incidence of program duplication and for refining the characteristics associated with the data link family. This detailed analysis was based on approximately 33 technical and functional descriptors. Functional block diagrams

Data Link Family	Descriptor									
	Type	Information Bandwidth (KHz)	Anti-Jam* (dB)	PI**	Crypto	Freq. Band Range	Range	From (Platform)	To (Platform)	Number of Users per Channel
I HF	Digital	3	0	6000	Yes	HF, 2-30 MHz	5556	Aircraft	Gnd. Fixed	one
II Low Data Rate	Digital	<100	0/25	2000	Yes	UHF, 1-20G	556	Aircraft	Aircraft	Variable
III Multiple User	Digital	30-300	25	29	Yes	UHF, 1-20G	556	Aircraft	Aircraft	Multiple
IV Wide Band	Digital	100-100M	0/25	1	No	UHF, 1-20G	556	Aircraft	Gnd. Trans.	one
V Integrated Expendable Sensor	Digital	20 C&S 1600 Video	25	3	No	UHF, 1-20G	370	Missile	Aircraft	Multiple C&S, one Video
VI E-O	Digital	3	0	<1	Yes	.5 Micron	LOS	Aircraft	Ship, Sub.	one

*Specifies the upper limit of the AJ processor protection for that family.
**Probability of Intercept Index.

Figure 2-13. REFINED DATA LINK FAMILY CHARACTERISTICS

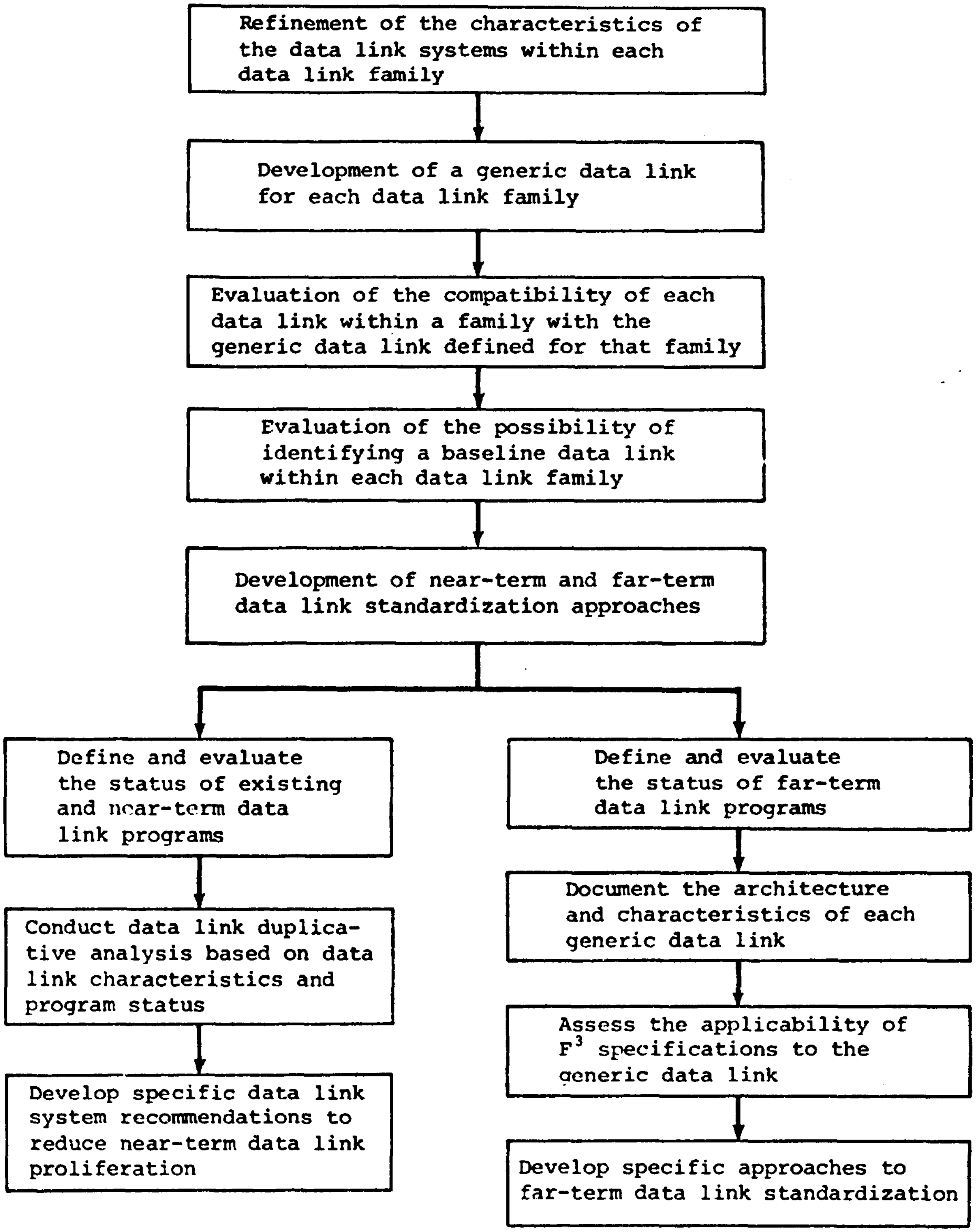


Figure 2-14. DATA LINK STANDARDIZATION ASSESSMENT METHODOLOGY

that indicate the black box configuration (i.e., architecture) were developed for each of the data links and dimensions, weights, and input power requirements were evaluated. This information was used to assess the architectural compatibility of the data links. The expanded set of descriptors and the interchangeability factors (dimensions, weight, power characteristics), listed in Table 2-3, were used in the development of generic data links for each family.

2.2.3 Development of Generic Data Links

The purpose of developing a generic data link for each data link family was to determine if a single data link could be defined that would be compatible with the characteristics of all of the data links within the family. The method used was to list the basic descriptors of the members of each family and, from this list, develop the composite technical characteristics of a generic data link. Each generic data link that evolved was defined by an envelope of technical characteristics that encompassed the characteristics of all of the data link systems within each of the families. Since the generic data link was all encompassing, it did not necessarily match the specific technical characteristics of each of the associated data link systems.

2.2.4 Evaluation of the Compatibility of each Data Link within a Family with the Generic Family Data Link

The purpose of the compatibility evaluation was to develop family generic data link options that would permit direct responsiveness to the specific characteristics of each data link within that family. The method used examined each data link within a family to determine if its technical characteristics were compatible with the generic data link. If discrepancies were detected, it was necessary to develop a range of options (e.g., high and low power amplifiers, and various types of antennas) to the basic generic data link. This resulted in a modular growth data link that was compatible with all the characteristics of the data links within a family.

2.2.5 Evaluation of the Possibility of Identifying a Baseline Data Link within Each Family

The purpose of this evaluation was to determine if a data link system within a family could be used as a basic data link from which a generic data link could be developed. The method used compared the technical characteristics and interchangeability factors of each of the data links within a family with the generic data link. Identification of a specific baseline system within each family was not possible because of the various architectures used in designing the data link systems. The partitioning of processing functions between the data link and source/sink subsystems of the analyzed systems resulted in different configurations that were tailored for each specific application. This precluded selecting one system that could be used, even with minor modifications, as the basis for developing the generic data link. As a result, two approaches were developed.

Table 2-3. EXPANDED SET OF DATA LINK DESCRIPTORS AND LRU INTERCHANGEABILITY FACTORS

BASIC DESCRIPTORS	FUNCTIONAL CHARACTERISTICS	LRU INTERCHANGEABILITY FACTORS
Information Bit Rate	Tx Power (Peak)	Dimensions
Processor AJ Margin	Duty Cycle	Weight
Crypto	Tx Bandwidth	Environmental Operating Conditions (Applicable MIL Specs)
Mode of Operation	Transmitted Bit Rate	Power Characteristics
Amount of Input Power	Type of Modulation	
Type of Input Power	Baseband Multiplexing	
No. of Available Channels	AJ Techniques	
No. of Users per Channel	Receiving Antenna Type	
Range	Receiving Antenna Beamwidth	
Relay: Available	Transmitting Antenna Type	
Relay: Required	Transmitting Antenna Beamwidth	
Frequency Band	Error Detection Type	
Allowable Bit Error Rate	Error Correction Type	
	Bandwidth Compression Ratio	
	Link Access Time	
	Level of BITE	
	Reliability	
	Maintainability	
	EMC (MIL-Spec)	
	Resolution (imagery only)	

2.2.6 Development of Near-Term and Far-Term Data Link Standardization Approaches

The two approaches developed are designated Near Term and Far Term. The near-term approach attempts to identify methods to reduce data link proliferation, through analysis of existing programs to identify duplicative programs and programs that may be consolidated. The far-term approach involves the application of F^3 specifications to the generic data links associated with each family to provide the basis for data link standardization in the future.

2.2.6.1 Near-Term Approach

The near-term approach, recognizing that standardization was not possible with existing links, concentrated on analyzing existing programs to determine ways of reducing proliferation, such as by termination or consolidation of programs. A duplicative analysis was conducted on the data links within each family. Specific characteristics and program status were compared to determine whether duplicative programs existed. Additional analyses were conducted on data links that performed the same or similar missions, but had slightly different operational characteristics, to determine if such programs could be consolidated.

2.2.6.1.1 Data Link Duplicative System Analysis

The objective of the Data Link Duplicative System Analysis was the identification of potential duplicate data links. The process consisted of computer comparisons of the basic descriptors associated with each data link within the complete study data base; then manually correlating and reducing the output. For each iteration of the computer program, one of the data links (the baseline system or parent) was compared with the remaining data links (potential duplicates). Duplication was considered from total match to total downward compatibility by progressively widening the constraining criteria. The descriptors and their constraining criteria are shown in Table 2-4. In the total match case, all of the constraining criteria had to be met; e.g., the frequency bands of the parent/duplicates had to be identical. No completely duplicate systems were identified as a result of this effort. The constraining criteria were progressively widened with the only constraint that of downward compatibility; e.g., the range of the duplicate had to be less than the range of the parent. This computer run resulted in a list of nine potential duplicates that were then manually analyzed. Additional constraints imposed during this analysis included examination of IOC dates to ensure that a potential duplicate system did not have an earlier IOC data than its parent. Duplication was considered only within a single data link family to enhance technical feasibility of the parent/duplicate equipment. Dimensions, weights, and power requirements were also evaluated. The complete analysis indicated that the nine potential duplicates, although exhibiting duplication in some areas, were not so identical that any one system could be replaced with another.

Table 2-4. POTENTIAL DUPLICATIVE SYSTEMS CRITERIA	
Descriptor	Typical Duplicate Condition
Freq. Band (FB)	$FB_D = FB_P$
Crypto (C)	$C_D = C_P$
Multiplex Mode (M)	$M_D = M_P$
Platform (P)	$\mathrm{Max}(P_{Df}, P_{Dt}) \leq \mathrm{Max}(P_{Pf}, P_{Pt})$ and $\mathrm{Min}(P_{Df}, P_{Dt}) \leq \mathrm{Min}(P_{Pf}, P_{Pt})$
AJ (AJ)	$AJ_D \leq AJ_P \leq AJ_D + 3\mathrm{dB}$
Range (R)	$R_D \leq R_P \leq 1.5R_D$
Info (BW)	$BW_D \leq BW_P \leq 1.5BW_D$
Transmitter Power (T_xP)	$(T_xP)_D \leq (T_xP)_P \leq 1.5(T_xP)_D$
D = Potential Duplicate; P = Parent (Baseline)	

2.2.6.1.2 Data Link Consolidation Analysis

The final step in the investigation of the near-term approach to reduction of proliferation was to assess the possibility of consolidating existing data link programs by making minor modifications to an existing data link to meet the requirements of another. The method used first analyzed the data base to identify systems that performed the same or similar operational missions. The results of the duplicative system analysis concerning the identified systems were then reviewed. Finally, the characteristics and functions of the data links associated with the systems that performed the same or similar operational missions were evaluated to determine if these programs could be consolidated. Possible areas of consolidation thus identified are presented in Chapter Three of this report.

2.2.6.2 Far-Term Approach

The final step in the methodology involved analysis of the status of far-term programs to identify programs that may be candidates for development on the basis of the generic data link configuration associated with the appropriate family. Each generic data link was examined for applicability of F^3 specifications, as set forth in the standards for electronic equipment by the Airlines Electronic Engineering Committee (AEEC). The possible candidate programs are evaluated in Chapter Three of this report.

The recommended far-term approach would use the defined data link family structure as the basis for meeting all far-term data link requirements. This structure can be accomplished by developing a generic modular growth data link for each of the six data link families. The development of these links should be based on F^3 specifications that standardize the interfaces between the data link and the user of the information handled by the links.

2.2.7 Summary

This section presented the methodology used to assess the potential for standardizing data links on the basis of the family structure evolved during this study. Two approaches evolved: the near term and the far term. The near-term approach recognizes that standardization is not possible with existing developmental links, but that it is possible to reduce data link proliferation by consolidating appropriate near-term programs and imposing a requirement that existing data links be used when possible to meet any new requirement. The far-term approach is based on development of a set of generic modular growth data links, each one associated with one of the six data link families, to provide the basis for meeting future data link requirements by means of a standard data link family.

2.3 ECONOMIC ANALYSIS

This section presents (1) an overview of the economic analysis, (2) candidate approaches considered for the economic analysis, (3) a discussion of the selected Life-Cycle-Cost Model (LCCM), (4) LCCM scenario, (5) LCCM program operation, and (6) application of the LCCM.

2.3.1 Overview of the Economic Analysis

The objective of this analysis was the determination of the potential economic benefits of the generic approach to data link standardization. The objective was accomplished by selecting a candidate data link family and comparing the expected life-cycle cost of the generic data link with the combined life-cycle costs of the data links that comprise the candidate family. The wide band data link family was selected for the analysis primarily because of its current high interest to DoD, the availability of development and production cost data, and the availability of production quantity data on the data links within that family. However, the cost data furnished by the Services was not sufficient in all cases and estimates based on engineering judgment and information from previous studies had to be used.

2.3.2 Candidate Approaches

A Life-Cycle-Cost Model is useful because it provides a basis for analyzing the elements of cost that will be encountered over the life of a system. Broadly speaking, the cost elements include development, investment, and support, each of which is comprised of a large number of sub-elements. A life-cycle cost run of a generic data link and the constituent data links of a family permits a comparison of the cost elements of each and indicates where significant cost savings could and could not be achieved.

The two approaches considered for the economic analysis were (1) develop a new LCCM specifically tailored to data links, or (2) use an existing model. Since there was available at ARINC Research an existing

LCCM that could be modified for use in the economic analysis, the latter approach was chosen. The existing LCCM was developed by ARINC Research for the Army User Equipment (UE) of the NAVSTAR Global Positioning System. It is capable of computing annually and cumulatively the expected value costs of Research, Development, Test, and Evaluation (RDT&E); procurement; installation; and Operation and Support (O&S) of equipment used in airborne, ship, vehicle, and manpack environments. The model was designed with a high degree of flexibility to enable rapid evaluation of a large number of UE alternatives and, thus, could be readily applied to evaluate specific data link terminals.

2.3.3 Selected LCCM

The selected LCCM consists of a main program and stored data files that are applied through the use of a time-share computer system. The data files are of two types:

(1) A Common Data File (COMFIL) -- contains data common to all program executions and is automatically read during program execution.

(2) Data Link Equipment Files -- each file is stored under a separate name; files contain data peculiar to a given data link terminal (i.e., air, ship, or ground terminal); files are called individually, by terminal input, during program execution.

2.3.4 LCCM Scenario

In order to compare, on a common basis, the life-cycle costs of the generic data link and the data links that are members of the wide band family, a scenario was developed based on the following primary conditions:

- Procurement and support was assumed to be accomplished by one service
- Commonality of modules and cards was not considered
- No inflation index was applied
- No discount rate was applied
- All units were assumed to be bought the first year following the DSARC production decision and were operated for the entire 10-year period

In addition, the system cost was allocated among the Line Replaceable Units (LRUs) because only system-level cost data were available.

2.3.5 LCCM Program Operation

Figure 2-15 is an overall flow diagram of the LCCM program that proceeds as follows:

- Ascertains from terminal inputs if sensitivity variations are intended and, if so, which parameters are to be varied. The

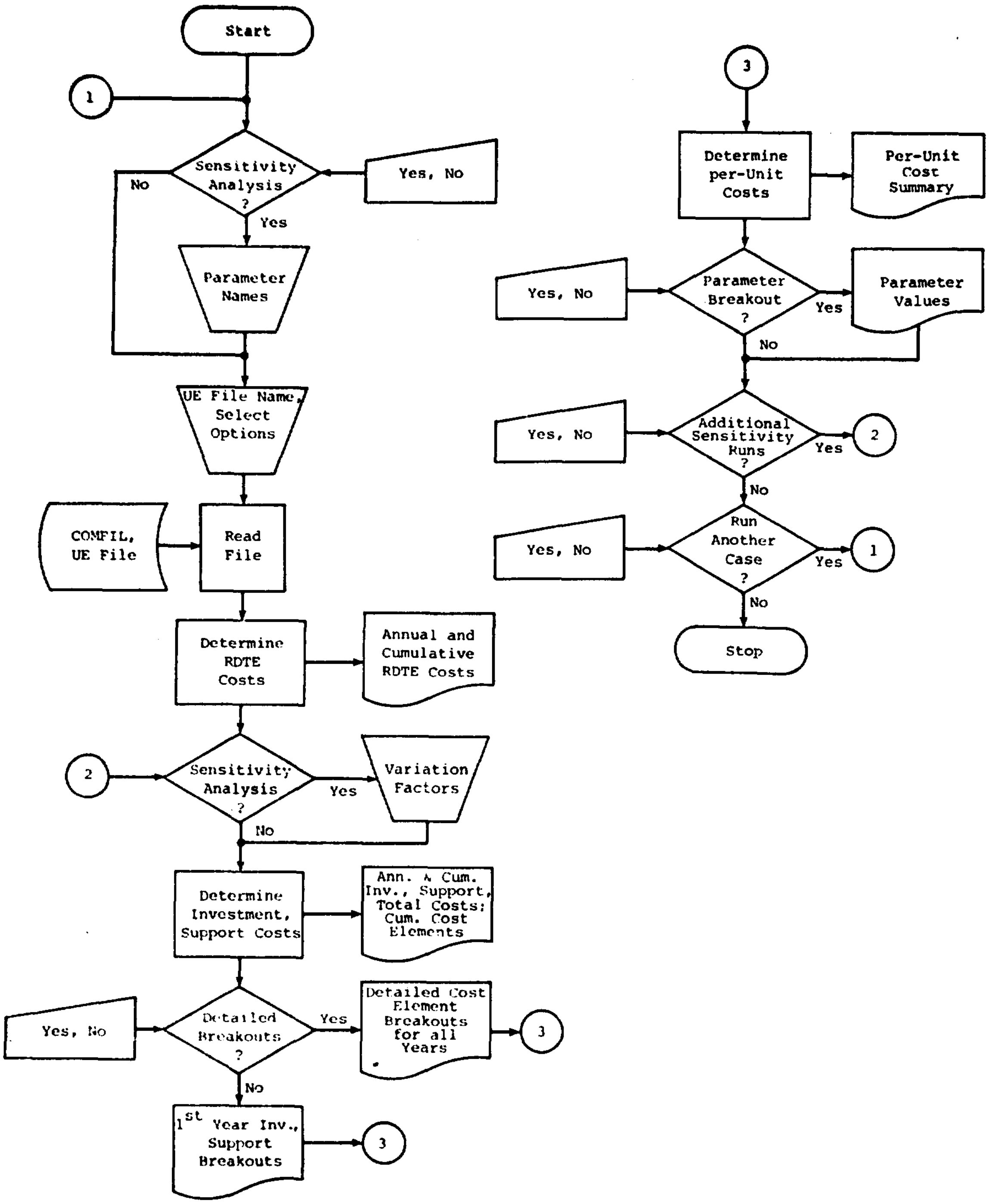


Figure 2-15. FLOW DIAGRAM OF LCCM PROGRAM

LCCM program is configured to accept up to 23 different parameters for sensitivity analysis variations. For example, the effect of Mean Time Between Failure (MTBF) on the life-cycle cost of a data link can be obtained by varying the MTBF.

- The specific data link file is identified and various analysis options are selected by terminal input.
- The common file and the designated data link file are read, RDT&E costs are calculated, and the total RDT&E annual and cumulative values are output to the terminal.
- If sensitivity analyses are being conducted, variation factors are input from the terminal for each of the designated parameters.
- Various investment and support cost elements are calculated and their composite annual and cumulative totals, with the overall annual and cumulative data link costs, are output to the terminal.
- Detailed annual breakouts of the RDT&E, investment, and support cost elements are also available as optional terminal outputs.

Details of the life-cycle-cost model are available in "Life-Cycle-Cost Model for Army User Equipment of NAVSTAR Global Positioning System", ARINC Research Publication 1172-02-1-1528, August 1976.

2.3.6 Application of the LCCM

Data files were developed on nine airborne data link terminals, one shipboard terminal, and eight ground terminals of the data links in the wide band family. The following is the list of the specific data links and associated terminals used in the economic analysis:

- Guardrail (Air)
- Tactical Reconnaissance Data Link (Air and Ground)
- UPD-4 (Air and Ground)
- AIDATS (Air and Ground)
- QSR (Air and Ground)
- CEFLY LANCER (Air and Ground)
- Compass Bright/Ears (Air and Ground)
- LAMPS III (Air and Shipboard)
- Advanced Sonobuoy Communications Link (Air)
- LEFOX GREY (MCA) (Ground)
- AGTELIS (Ground)

Also, data files were developed for a wide band generic data link (air and ground) based on cost estimates derived from discussions with data link contractors and cost/quantity information submitted by the Services.

The assumptions used in developing the data link equipment files and the common data file are presented in Appendix E. Expected life-cycle costs for data link equipment were calculated by the LCCM on the basis of the values of the input parameters in the files. In addition, to determine the sensitivity of the results obtained to the parameter values, the wide band generic data link was evaluated for selected parameter variations.

The values of each of the cost elements obtained from each of the wide band data link model exercises were then added to obtain the composite costs of the wide band data links. These composite costs were compared with the same cost element of the generic data link. The results of the analysis are presented in Chapter Three. The results of the sensitivity variations are also presented.

CHAPTER THREE

PRESENTATION AND EVALUATION OF RESULTS

3.1 DEFINITION OF GENERIC DATA LINK FUNCTIONS

As discussed in Chapter Two and illustrated in Figure 2-12, the data links considered to be within the scope of this evaluation have been analyzed and categorized into six families. Within each family, representative data links were examined to identify common characteristics. Analysis of these data links yielded an identification and definition of generic data link functions that are separate from the functions that should be performed by the source and sink subsystems. The analyses also showed that, in some applications, a wide range of system standardization can be achieved if the signal conditioner/reconditioner functions are excluded from the basic data link. Thus, a result of the analyses is the organization of generic data links into two categories: Basic Data Link and Extended Data Link.

A simplified representation of a typical generic data link, showing the basic data link, the extended data link, and the interfaces with the source and sink subsystems is shown in Figure 3-1. The figure represents one terminal of a full-duplex (FDX) data link; the other FDX terminal would have the same organization and functional allocation. A simplex data link would be a sub-set of the FDX data link, having one source subsystem and, normally, one sink subsystem.

3.1.1 Basic Data Link

The basic data link shown in Figure 3-1 includes a data modulator, a data demodulator, RF portions of the system (including antennas), and the controls necessary for the operation of the basic data link (e.g., frequency, mode, antenna). The input to the basic data link is a digital stream of data processed for transmission by the signal conditioner, in accordance with the requirements of the individual source system. The output from the basic data link is a digital stream of data to the signal reconditioner that returns the transmitted data to a form suitable for use by the sink subsystem.

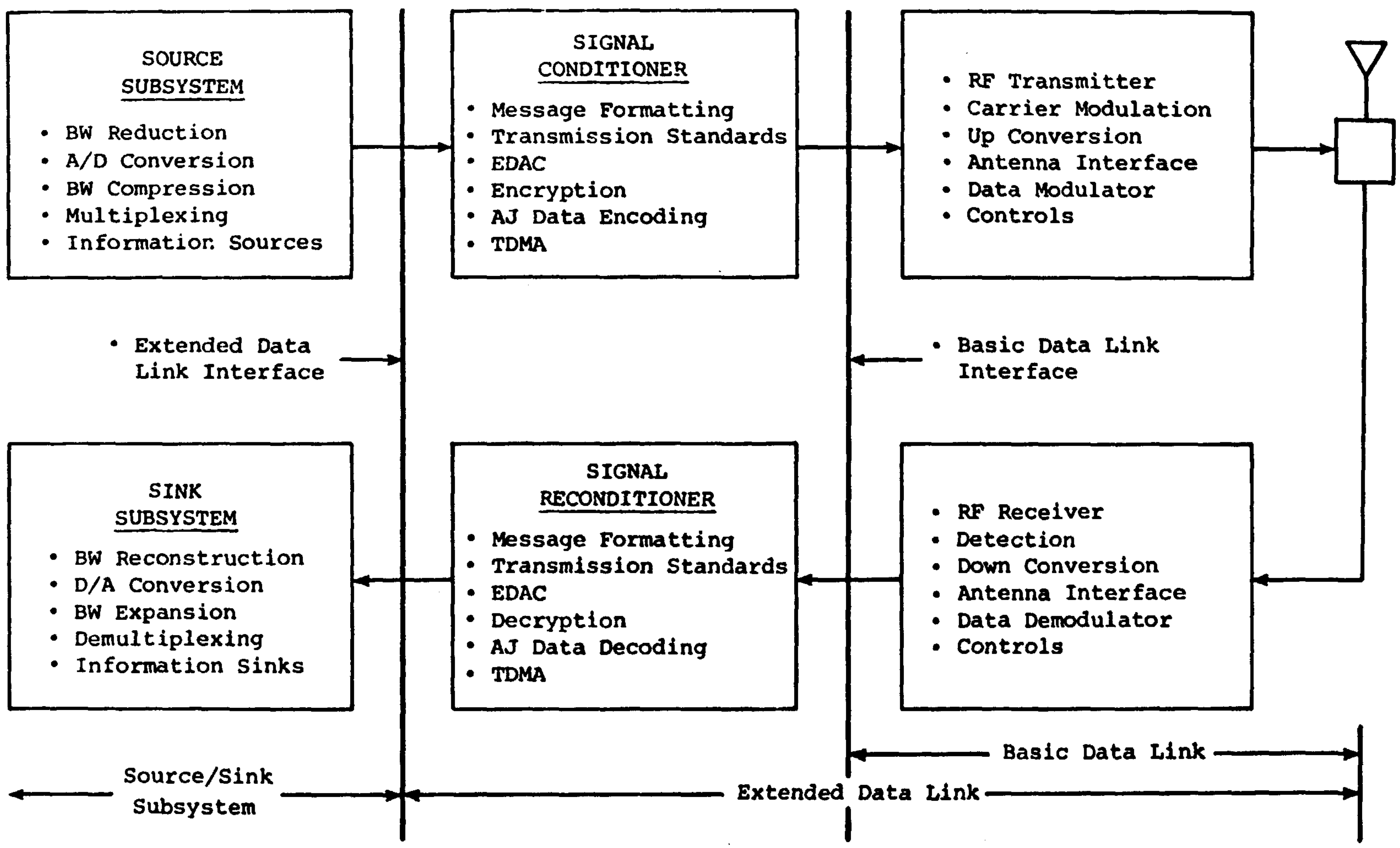


Figure 3-1. SIMPLIFIED TYPICAL GENERIC DATA LINK

3.1.2 Extended Data Link

The extended data link shown in Figure 3-1 includes the basic data link functions as well as those of the signal conditioner and signal reconditioner.

The signal conditioner portion of the extended data link includes those functions that are associated with the exchange of digital data over RF transmission paths, namely:

- Message Formatting
- Transmission Standards
- Error Detection and Correction (EDAC)
- Encryption (CRYPTO)
- AJ Data Encoding
- Time Division Multiple Access (TDMA) Control

All data links require the definition and implementation of message formats and transmission standards. However, the remaining functions will depend upon individual system applications. Most data links will incorporate some level of EDAC unless the data contains extensive redundancy (e.g., imagery); CRYPTO will only be employed where data security is required (e.g., probably for SIGINT, probably not for imagery); AJ data encoding/decoding will be incorporated on those links where a sufficient AJ margin does not exist without incorporating this type of processor gain; and TDMA functions will only be incorporated when the requirement exists to accommodate a number of users simultaneously (e.g., JTIDS-type applications).

The signal reconditioner portion of the extended data link includes those counterpart functions to the signal conditioner that are necessary to return the transmitted digital signal to a form usable by the sink subsystem, namely:

- Message Formatting
- Transmission Standards
- Error Detection and Correction (EDAC)
- Decryption (CRYPTO)
- AJ Data Decoding
- Time Division Multiple Access (TDMA) Control

3.1.3 Source Subsystem

The source subsystem consists of one or more information sources. The output of the source subsystem is a digital data stream that represents the baseband information outputs of single or combined sources. In addition to the normal functions that the source subsystem must perform, several other functions may be required to reduce the output to a baseband digital data stream suitable for exchange with the extended data link. These source subsystem digital output functions include:

- Bandwidth (BW) Reduction - reducing the BW of the output signal by reducing the amount of information transmitted, using such techniques as frame rate reduction and resolution reduction
- A/D Conversion - conversion of the analog signal to a digital form
- BW Compression - decreasing the BW occupied by the output signal by mathematical techniques such as Fourier or Hadamard transforms
- Multiplexing - combining the outputs of more than one source into a single output data stream

These functions are very closely related to the requirements of the individual information sources and must be designed to accommodate these requirements. These functions should not be incorporated in the signal conditioner portion of the extended data link, since the application of the extended data link to serve other source subsystems would then be severely restricted.

3.1.4 Sink Subsystem

The sink subsystem includes those counterpart functions, to the source subsystem, that are necessary to process the output of the data link signal reconditioner into a form usable to the individual sinks. These sink subsystem digital input functions include:

- BW Reconstruction - Restoration of the original signal characteristics that were distorted by BW reduction techniques
- D/A Conversion - conversion of the digital signal to analog form
- BW Expansion - expanding the BW of the data stream by using the converse of the mathematical technique used for compression
- Demultiplexing - separating the single input data stream into multiple data streams and providing them to individual sinks

3.2 ORGANIZATION OF GENERIC DATA LINKS

The generic data link information presented in Figure 3-1 is shown in an expanded form in Figure 3-2 -- an Overall Generic Data Link. This overall link is organized to encompass the characteristics of the generic data links for all of the families presented previously in Figure 2-12. However, certain data link functions shown in Figure 3-2 will not be applicable to all families (e.g., AJ data encoding would not normally be applicable to the HF data link family). In addition, certain functions should be included as option items for both the basic and extended data links in the various data link families (e.g., CRYPTO, PA power).

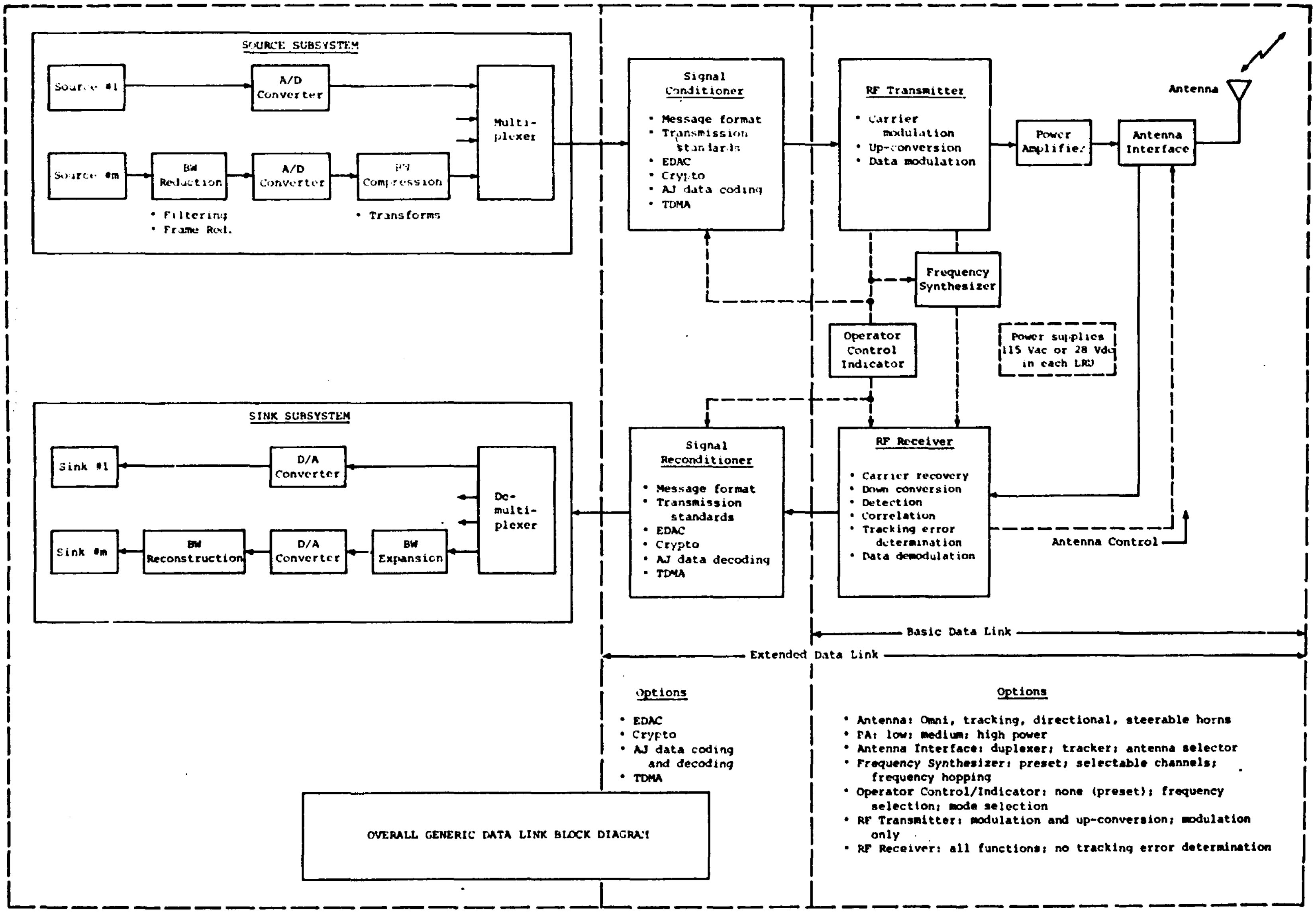


Figure 3-2. OVERALL GENERIC DATA LINK BLOCK DIAGRAM

Block diagrams for the generic data links for each of the data link families are discussed in the following subsections.

3.2.1 HF Data Link Family

Figure 3-3 presents a block diagram of the generic data link in the HF Data Link Family. HF is normally used in applications where "beyond line of sight" (BLOS) operation is required. The link is inherently a narrow band data link and, as such, is restricted to low data rates. Therefore, as shown in Figure 3-3, the generic HF data link will normally serve a single source and sink within the source and sink subsystems. However, the numbers of sources and sinks are of no concern to the data link, provided the baseband digital data stream is of low enough rate to be within the capabilities of the data link. EDAC and CRYPTO are included only as option items to be incorporated when required for a particular application. AJ data encoding/decoding and TDMA functions have been deleted from the list of possible signal conditioner/reconditioner functions because of the limited bandwidth of the HF data link family. No up- or down-conversion or frequency hopping capabilities are shown because of the relatively low frequency of the RF carrier. No tracking antennas are shown because of the difficulty of implementing this capability at HF.

3.2.2 Low Data Rate (LDR) Family

Figure 3-4 presents a block diagram of the generic data link in the Low Data Rate (LDR) Family. This data link is often used to exchange command and status data without incorporated AJ processing gain. Because of its low data rate characteristics, Figure 3-4 indicates that the generic LDR data link will normally serve a single source and sink within the source and sink subsystems. EDAC and CRYPTO are included only as option items to be incorporated when required for the particular application. AJ data encoding/decoding and TDMA have been deleted from the list because of the low data rate characteristics of the data link.

3.2.3 TDMA/Multiple User Family

Figure 3-5 presents a block diagram of the generic data link in the TDMA/Multiple User Family. This type of data link is used where multiple users must be serviced nearly simultaneously. EDAC and CRYPTO are included only as option items to be incorporated when required for a particular application. All other generic data link functions have been retained. Only an omni-directional antenna is shown because the locations of the multiple users will be diverse and, in many cases, not known. Otherwise, all basic data link options have been retained.

3.2.4 Wide Band (WB) Family

Figure 3-6 presents a block diagram of the generic data link in the Wide Band (WB) Family. This type of data link is normally used for transmission of inherently wide band information (e.g., imagery, SIGINT)

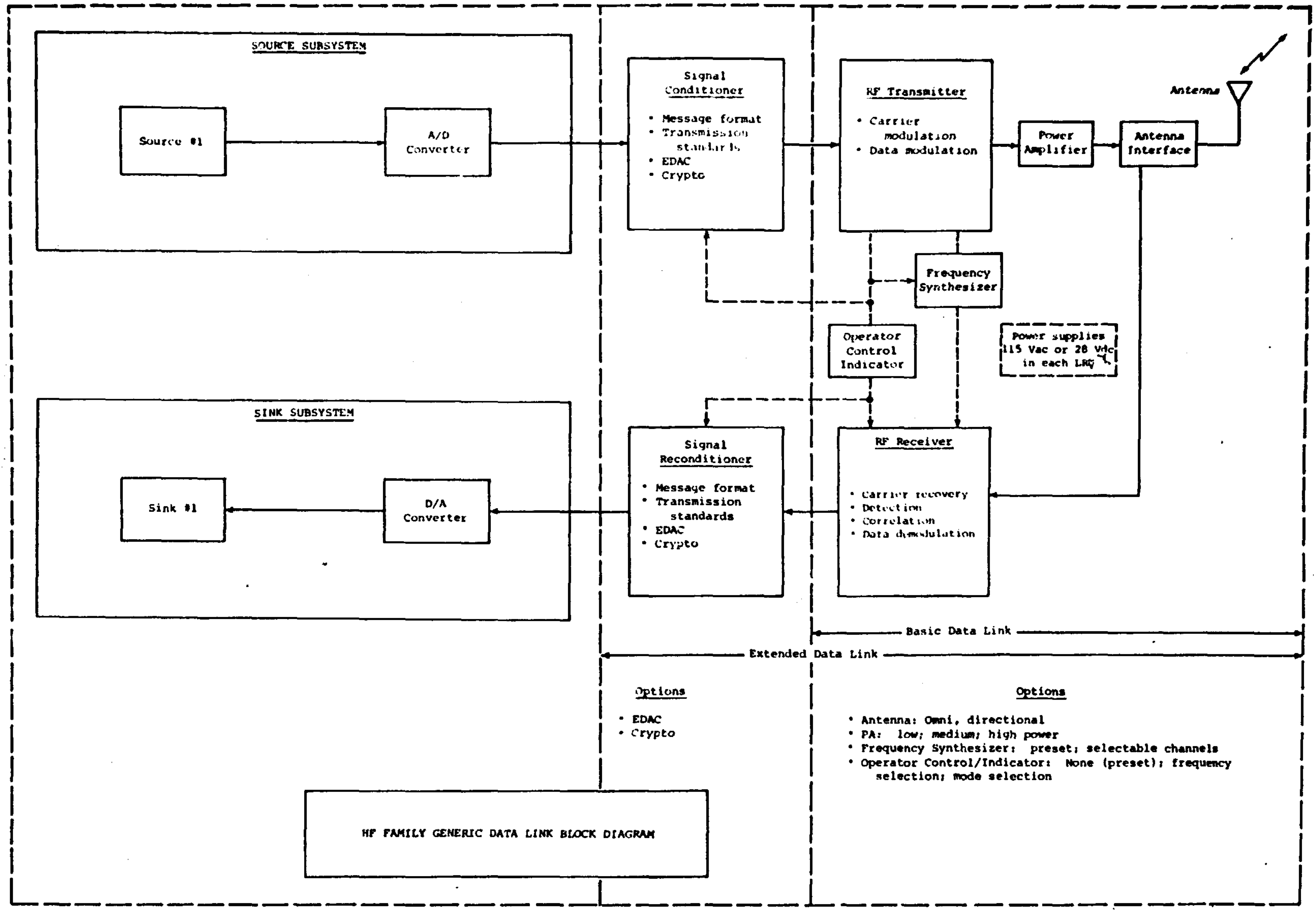


Figure 3-3. HF FAMILY GENERIC DATA LINK BLOCK DIAGRAM

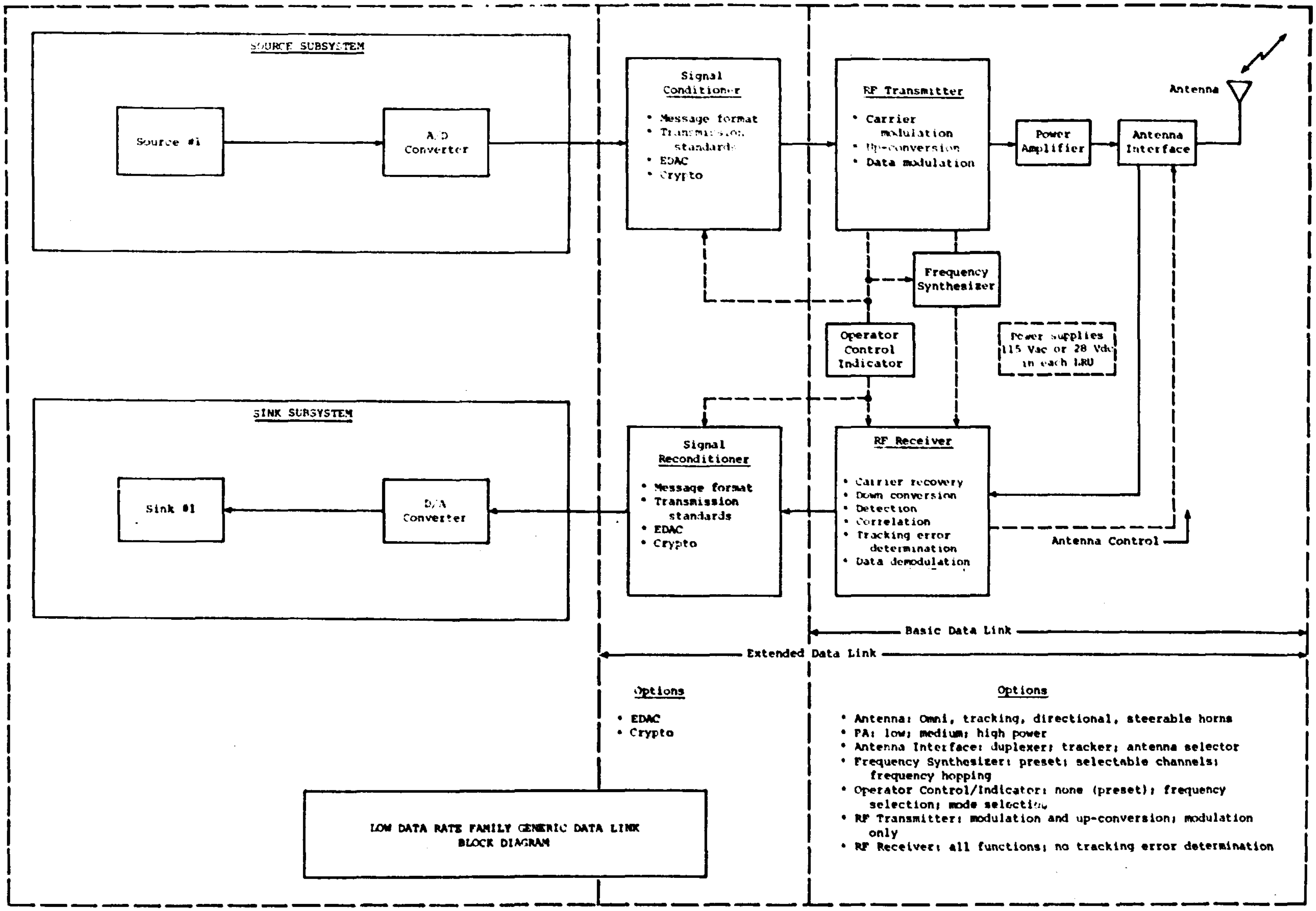


Figure 3-4. LOW DATA RATE FAMILY GENERIC DATA LINK BLOCK DIAGRAM

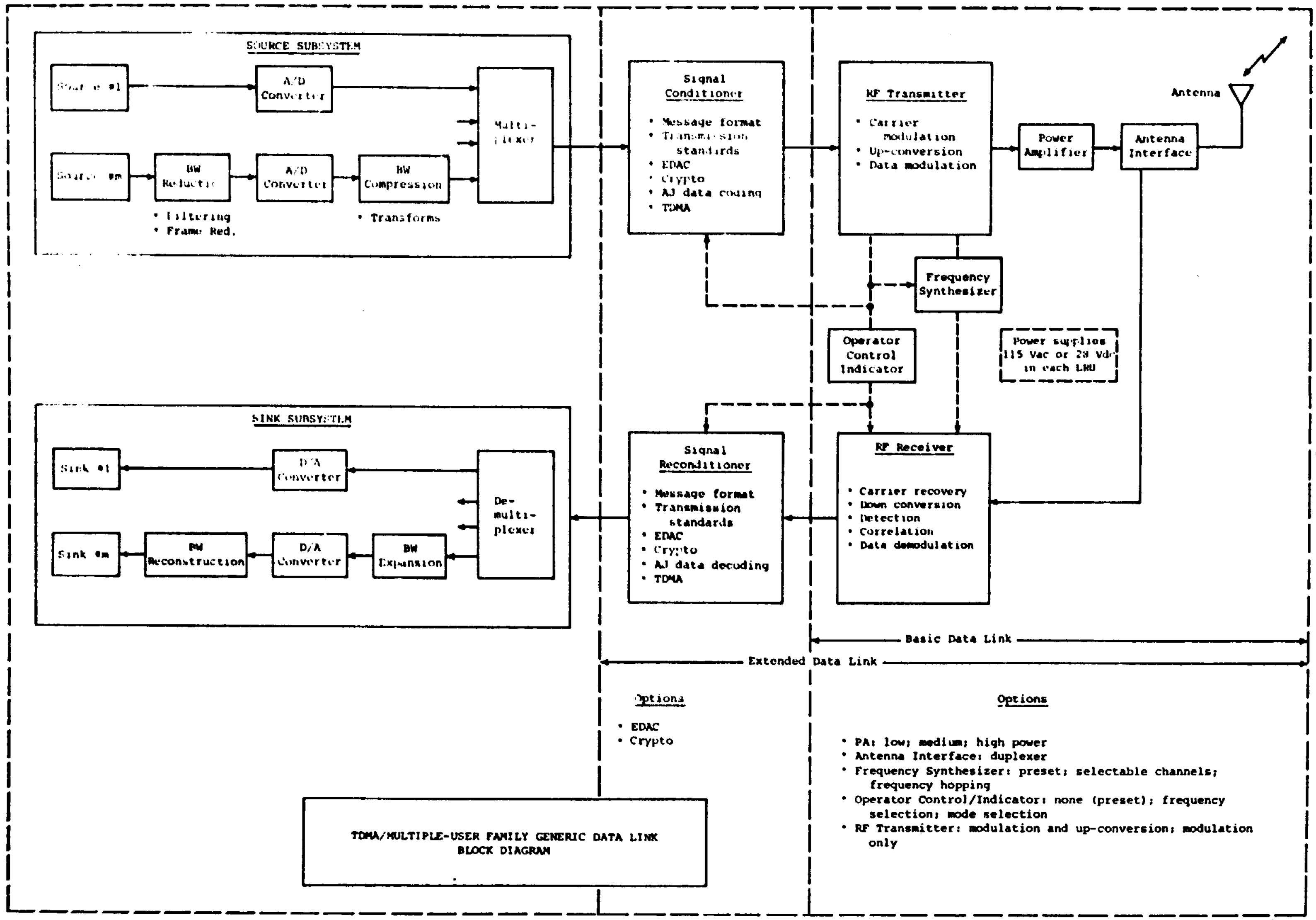


Figure 3-5. TDMA/MULTIPLE-USER FAMILY GENERIC DATA LINK BLOCK DIAGRAM

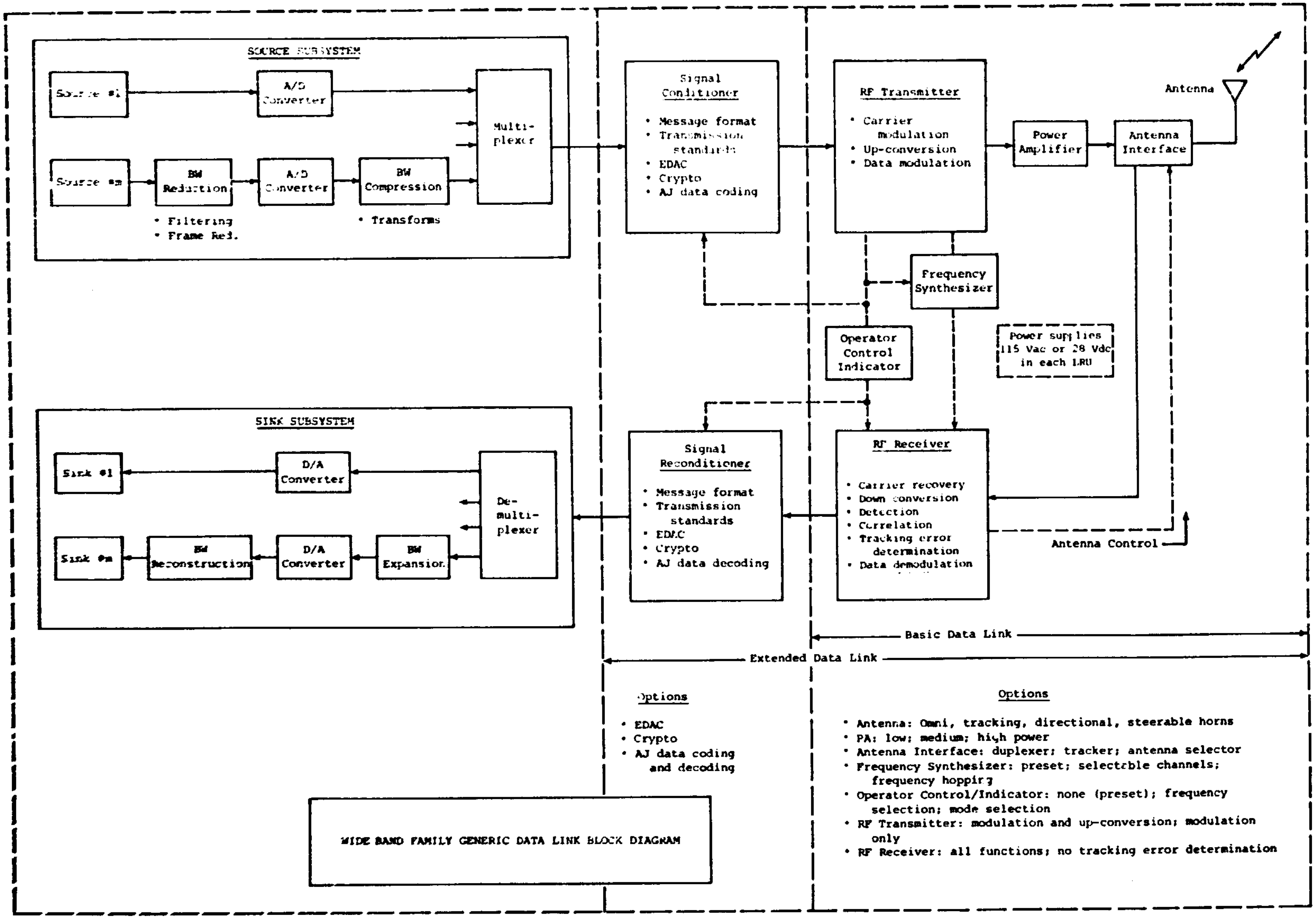


Figure 3-6. **WIDE BAND FAMILY GENERIC DATA LINK BLOCK DIAGRAM**

or for the transmission of inherently narrow band information (e.g., command) to which AJ processing gain has been applied. Only the TDMA function has been deleted from the generic data link functional characteristics. EDAC, CRYPTO, and AJ data encoding/decoding are included only as option items to be incorporated when required for a particular application. All basic data link option items have been retained.

3.2.5 Integrated (WB/C&S)/Expendable Family

Figure 3-7 presents a block diagram of the generic data link in the Integrated (Wide Band/Command and Status)/Expendable Family. Typical applications of this family would be expendable mini-RPVs and glide bombs where it is appropriate to integrate portions of the wide band data link with portions of the command and status data link to achieve savings in weight and size. Its functions and options for the wide band portion of the basic and extended data links are similar to those of the wide band data link family. The functions of the command and status links are similar to those of the LDR data link family shown in Figure 3-4. The type of integration between the two data links will vary with the individual application, but may include sharing of hardware (e.g., frequency synthesizer, antenna) or the sharing of functions (e.g., transmission standards).

3.2.6 Electro-Optical (EO) Family

Figure 3-8 presents a block diagram of the generic data link in the Electro-Optical (EO) Family. Application of such a family would be line-of-sight (LOS) and where atmospheric attenuation of optical transmissions is minimum. The family is characterized by narrow transmission beam widths that require the use of aimed antennas. Only the TDMA function has been deleted from the signal conditioner/reconditioner area in the generic data link functional characteristics. EDAC, CRYPTO, and AJ data encoding/decoding are included as option items to be incorporated on an "as required" basis. In the basic data link area, the RF portions have been changed to EO; only directional, possibly tracking, antennas are permitted.

3.3 STANDARDIZATION AND COMMONALITY OF DATA LINKS

As previously stated, data links have been organized into the Basic Data Link and the Extended Data Link categories. The Extended Data Link includes all functions that are associated with the exchange of data over RF transmission paths. The Basic Data Link is limited primarily to the RF and data modulation functions, excluding the signal conditioner/reconditioner functions. Standardization and commonality are more readily implemented at the basic data link interface than at the extended data link interface. However, the achievement of standardization or commonality at the Extended Data Link interface results in the realization of significantly greater benefits.

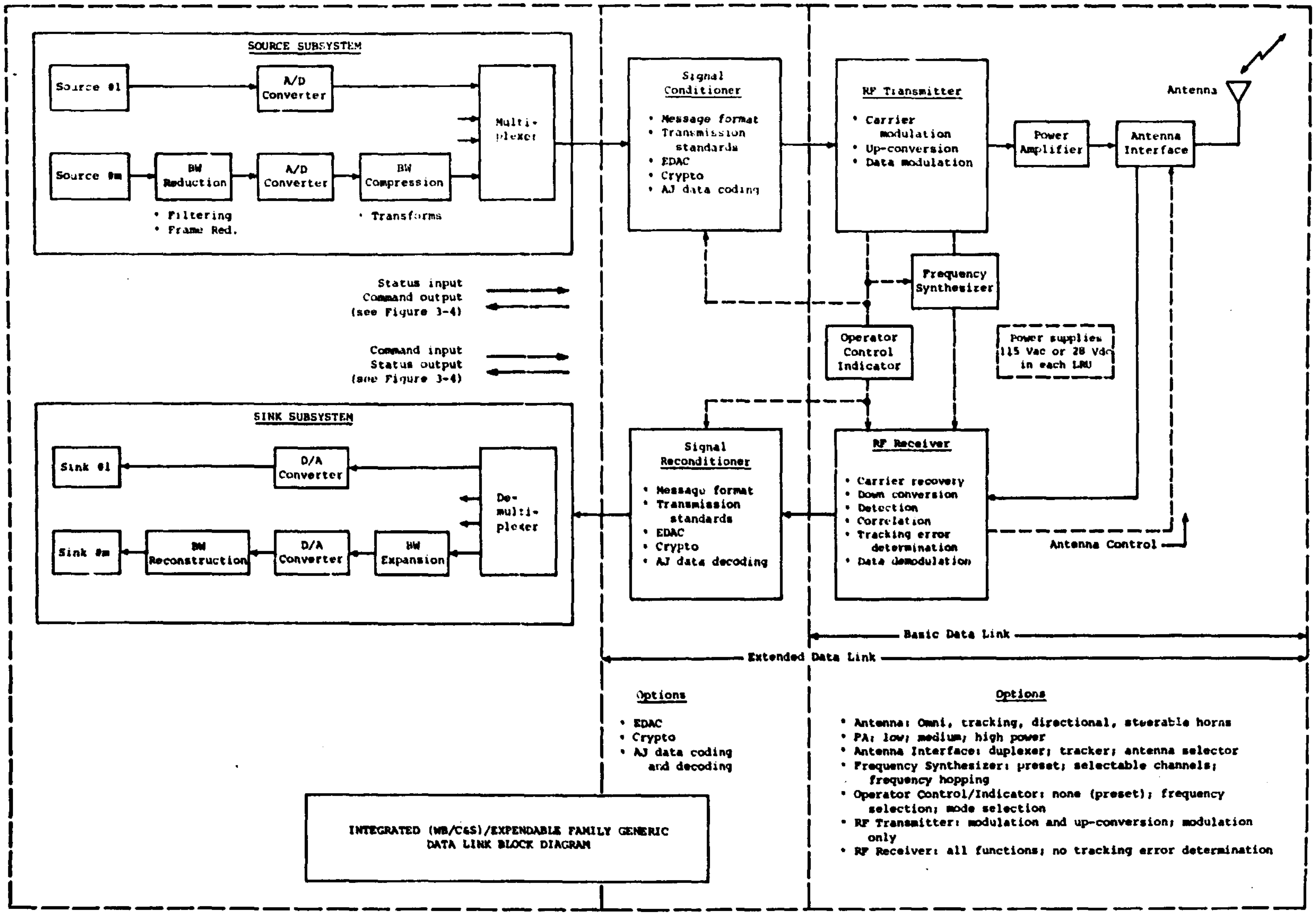


Figure 3-7. INTEGRATED (WB/C&S)/EXPENDABLE FAMILY GENERIC DATA BLOCK DIAGRAM

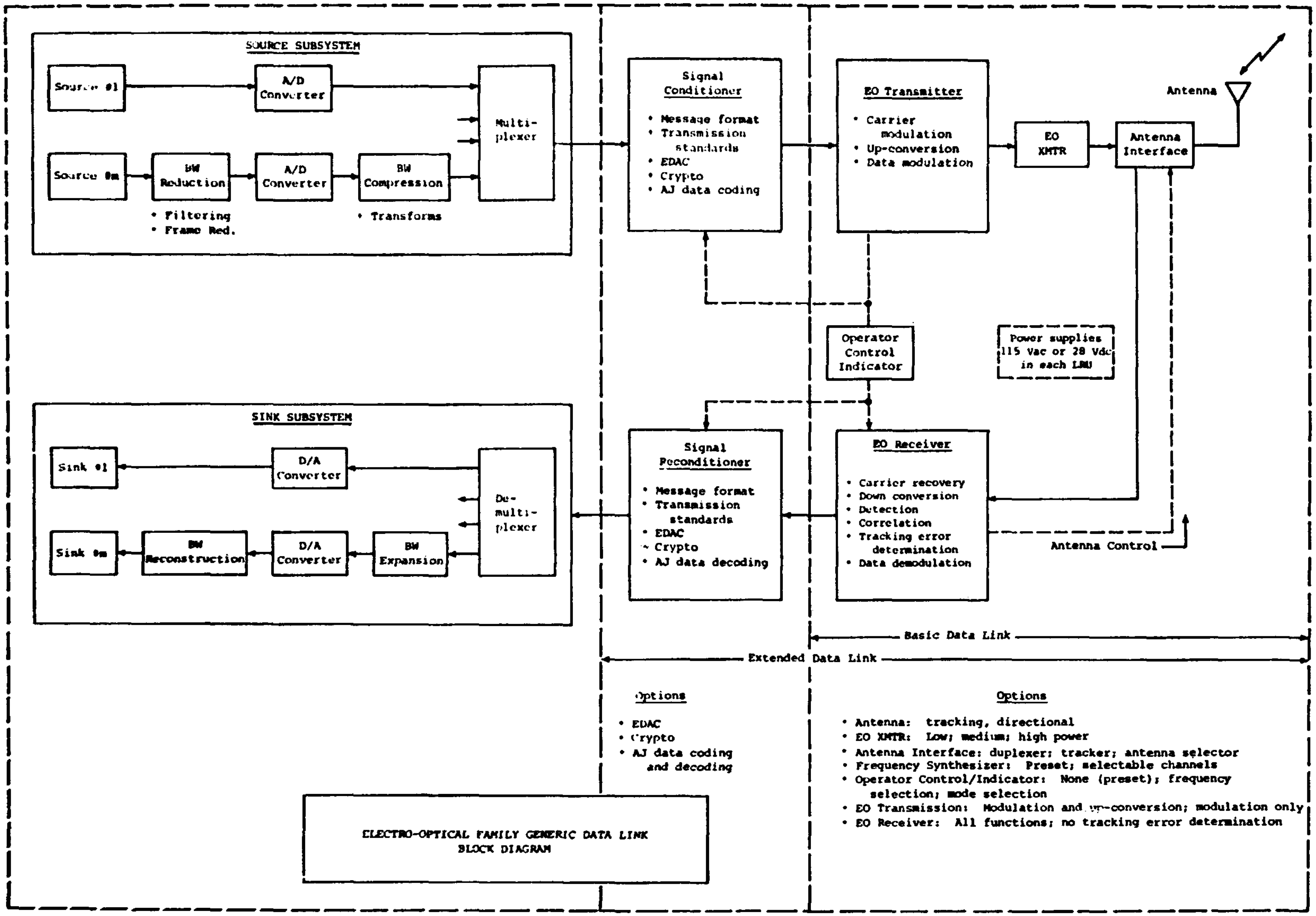


Figure 3-8. **ELECTRO-OPTICAL FAMILY GENERIC DATA LINK BLOCK DIAGRAM**

Standardization and commonality in the near term may have to be limited, in most instances, to the basic data link interface. However, standardization in the far term should be based on the extended data link interface. In both the near-term and far-term cases, commonality and standardization across data link family boundaries can only be expected to be implemented at the basic data link interface.

Standardization of current data link programs is discussed in Section 3.4.

Standardization of future data link developments is discussed in Section 3.5.

3.3.1 Application of Form, Fit, and Function (F^3) Characteristics

Data link standardization efforts in the past have been based primarily on reprocurement of equipment identical to existing designs. Significant cost reductions can be achieved by this method, but this technique freezes designs and prohibits realizing the benefits associated with the evolutionary technology advances that are characteristic of data link systems. Any standardization approach that freezes on specific designs is not consistent with the DoD need for frequent design upgrading to improve equipment reliability and performance.

The key to successful standardization is to provide an approach that is consistent with the need for continuing design upgrading, and achieving reliability improvement and reduced costs. Interface standardization (form-fit-function specifications) at the black box or LRU level is the standardization approach that encourages the simultaneous existence of several interchangeable designs of like equipment so that a user may choose among designs and prices.

As used in the airline industry, form, fit, and function implies the combination of interface and functional specifications that precisely and completely address the required mechanical, electrical, and environmental interfaces, together with the required equipment functions and performance. The F^3 approach has the advantage that while the interface is standardized, the internal configuration of the unit can evolve as technology changes, taking advantage of new devices and new materials. Moreover, interchangeability between the old and new generations of electronics becomes a practical reality, and the need for modification to accommodate new equipment is eliminated. With interface standardization, production costs can be held down by competition among interchangeable designs, and new systems can be synthesized, largely from proven standard units.

To achieve potential benefits, the feasibility of apply F^3 characteristics to effect standardization of data links was examined. Criteria for F^3 characteristic applicability were formulated on the basis of previous ARINC Research studies*, and are divided into three areas: general, equipment,

**Application of the Commercial Airline Acquisition Methodology (CAAM) to Department of the Navy Electronic Equipment Acquisitions*, ARINC Research Corporation, 15 October 1975.

Selection Criterion	Rationale	Assessment
I General		
• There is common equipment with wide application	• Equipment should be of common use to several DoD users to generate design and price competition.	• The generic data links are envisioned to be the far term standard data links that will be used by all of the services.
• Standards are developed in an open forum	• User-supplier interaction to integrate user requirements with supplier capabilities is imperative to the development of F^3 characteristics.	• A committee similar to the Airlines Electronic Engineering Committee (AEEC) will have to be set up to integrate the user requirements with the equipment developing agencies. To the extent possible, contractors should be included on the committee.
• Sufficient time is available to develop F^3 characteristics	• Experience has shown that up to one year may be required to formulate and obtain concensus on a characteristic. Development of a characteristic should be initiated from one to two years prior to a production procurement.	• Implementation of the generic data links is far enough in the future to permit the development and acceptance of the characteristic.
II Equipment		
• Equipment uses proven designs	• Equipment resulting from F^3 characteristics typically employ current technology and proven design.	• In general, new data links have evolved from older proven designs.
• Equipment can be described by Form, Fit, Function (F^3) standards	• Equipment should be definable by a F^3 characteristic where mechanical, electrical and environmental interfaces can be specified with the required functions and performance. Innovation within the "black box" is encouraged.	• Generic data link equipment can be described by F^3 standards. For example, the USAF has experience in F^3 applications as shown by their avionics standardization program and the AN/ARN-118 program. The airline community has developed a draft F^3 characteristic for a Universal Digital Data Link (UDDL).
• Equipment is reasonably self-contained	• To facilitate F^3 characteristics development, the equipment should be an independently operating "black box" such as a Line Replaceable Unit (LRU). Large-scale systems can also be used if they can be separated into independently functioning subassemblies.	• The generic data links are proposed to consist of Line Replaceable Units (LRUs)
• Equipment uses standard cases	• F^3 characteristics typically specify a family of ATR cases in order to facilitate generation interchangeability and quick "remove and replace" regardless of the individual manufacturer.	• Cases for generic data links could be made available in standard sizes.
III Procurement		
• There are multiple competitive suppliers	• Multiple suppliers of the desired equipment should be available to foster competition in both price and design.	• Investigation has shown there are numerous vendors that can supply this competition; e.g., the multiple user and wide band areas.

Figure 3-9. F^3 CHARACTERISTIC APPLICABILITY CRITERIA

and procurement. All areas were considered of equal importance in assessing the applicability of F^3 characteristics to the far-term generic data links. These criteria are presented in Figure 3-9, which contains an assessment of the applicability of the criteria to the generic data links.

The assessment of the applicability of F^3 characteristics to the far-term generic data links indicates that the approach could be readily applied to many of the generic data links or Line Replaceable Units (LRU). In applying the F^3 characteristics, each LRU shown in Figure 3-2 would be defined and the F^3 characteristics for the LRU interfacing with the external system would define the F^3 requirements at either the basic data link interface (RF Transmitter/Receiver) or the extended data link interface (signal conditioner/signal reconditioner).

3.3.2 F^3 Parameters

The types of F^3 parameters that must be defined for each LRU are as follows:

- Form of LRU
  - Size
  - Shape
  - Controls
  - Indicators
  - Panel Layouts
- Fit of LRU
  - Connectors and Identification Indexing
  - Standard Interwiring
  - Power Circuitry
  - Weight
  - Environmental Characteristics
- Function of LRU
  - Performance
  - Signal Outputs (Referenced to Input Stimuli)
  - Signal Characteristics (Waveforms)
  - Signal Coding
  - Signal Processing
  - Control Operation
  - Timing/Synchronization
  - Initialization

3.3.3 A Potential Data Link Acquisition Methodology

A number of complex factors must be addressed to successfully implement the F^3 characteristic as a basis for procuring data links within the DoD. Further, the F^3 approach is, in reality, only one element of an overall procurement approach, commonly designated the Commercial Airline Acquisition Methodology. The following paragraphs describe a hypothetical data link acquisition methodology to illustrate how the F^3 characteristic fits into an overall procurement methodology, and to illustrate some of the factors involved in the use of the F^3 characteristic in the DoD. The data link acquisition methodology, as described herein, could be used to acquire links comprised of off-the-shelf components that need little or no development effort. It should not be interpreted as applying to all data links. However, the activities that are shown to be necessary during the Requirements Determination and Characteristic Development phases would be common to the acquisition of all data links if the F^3 approach is applicable.

Implementation of the Acquisition Methodology described herein would require advanced planning and coordination to overcome human resistance to changes in the Services' current acquisition methodologies. Endorsement by the DoD and the Services is imperative for the success of this approach. The new methodology would require exceptional management attention, at least initially. The Acquisition Methodology can significantly increase the opportunity for cost benefit and serve to create a continuing market for the competitive procurement of data link equipment on an off-the-shelf basis, to the advantage of the Services.

The methodology has been divided into four phases: Requirement Determination; Characteristic Development; Equipment Development; and Procurement, Operation, and Maintenance. The phases reflect the completion of significant acquisition program milestones rather than the identification of requirements for higher-level management decisions. The general sequence of activities common to each phase is discussed in the following paragraphs. Figure 3-10, a flow diagram of the Acquisition Methodology, illustrates the sequence of activities and their relationships.

The approval of an operational requirement or the establishment of a data link equipment need within one of the Services initiates the Requirements Determination phase. The F^3 characteristic applicability criteria should be used to evaluate the technique during the acquisition program and the results should be carefully documented for subsequent comparison. It is emphasized that the F^3 characteristic applicability criteria are generally qualitative and are intended to indicate the basic feasibility of the approach. A decision to use the F^3 characteristic should not be made lightly, since it involves exceptional management and restructured procurement, administrative, and logistics provisions. When it is determined that the requirement meets the criteria for application of the F^3 characteristic, the Requirements Determination phase ends and the Characteristic Development phase starts.

During the Characteristic Development phase, appropriate management personnel are designated, plans are prepared, a Data Link Engineering Committee is formed, and an F^3 Characteristic and Minimum Performance Standards are written. Depending upon the complexity and features of the equipment, it is anticipated that this phase should take approximately one year to complete. The Data Link Engineering Committee is the recommended mechanism to permit the Services to include the commercial community in the development of the characteristic for the intended data link equipment. The ultimate application of the characteristic influences its overall content and is the major reason for separating the characteristic into parts reflecting the constraints of technical performance and the variables of procurement. The Minimum Performance Standards should include the minimum operating parameters, along with the test procedures necessary to demonstrate their performance in a defined operating environment. Approval of the characteristics completes the Characteristic Development phase and starts the Equipment Development phase.

The specific applicability of the activities described in the final two phases of the methodology has not been determined. The descriptions of these phases are included to provide the reader with an understanding of an overall acquisition methodology that makes use of F^3 characteristics.

It is ARINC Research Corporation's belief that an overall Acquisition Methodology such as that described could be applied to data links comprised of off-the-shelf components that require little or no development effort.

During the Equipment Development phase, competing manufacturers' equipment are selected for initial procurement through the use of two-step formal advertising. While the various suppliers complete their design and manufacture of equipment to satisfy the characteristic and testing of their equipment in accordance with the Minimum Performance Standards, the Department of Defense prepares for the issuance of a Request for Technical Proposals. In response to the Solicitation for Technical Proposals, manufacturers submit their proposals and bid samples of their products. The Equipment Development phase concludes with the selection of at least two manufacturers for procurement of their products.

The Procurement, Operation, and Maintenance phase is the last phase of the Acquisition Methodology. It begins with the award of the contracts to meet the initial equipment requirements and concludes when the using commands accept organic operation and maintenance responsibility for the procured equipment. Although contract-required manufacturer participation will cease, voluntary participation in the activities of the Data Link Engineering Committee and the Material Commands should continue as long as they see a potential for future sales of similar equipment.

To apply the Acquisition Methodology to new data link programs would require refinement to permit its incorporation into the funding structure of the DoD.

3.4 ANALYSIS OF CURRENT DATA LINK PROGRAMS

The current data link programs shown in Figure 2-12 were analyzed to determine if any programs were duplicative and should be terminated. New developmental data link programs shown in Figure 2-12 were also analyzed to determine if any planned data links could be consolidated with other current data links.

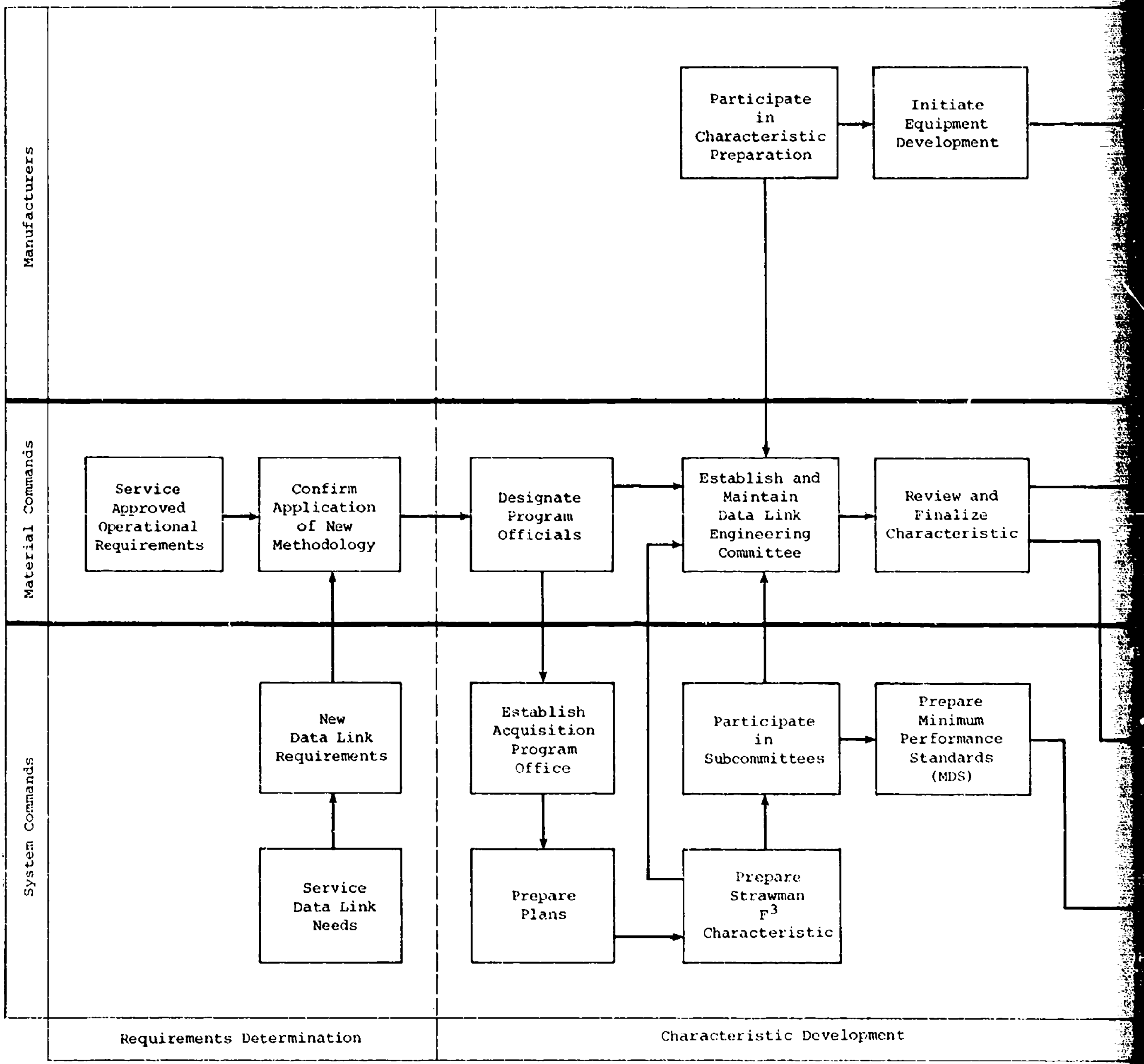
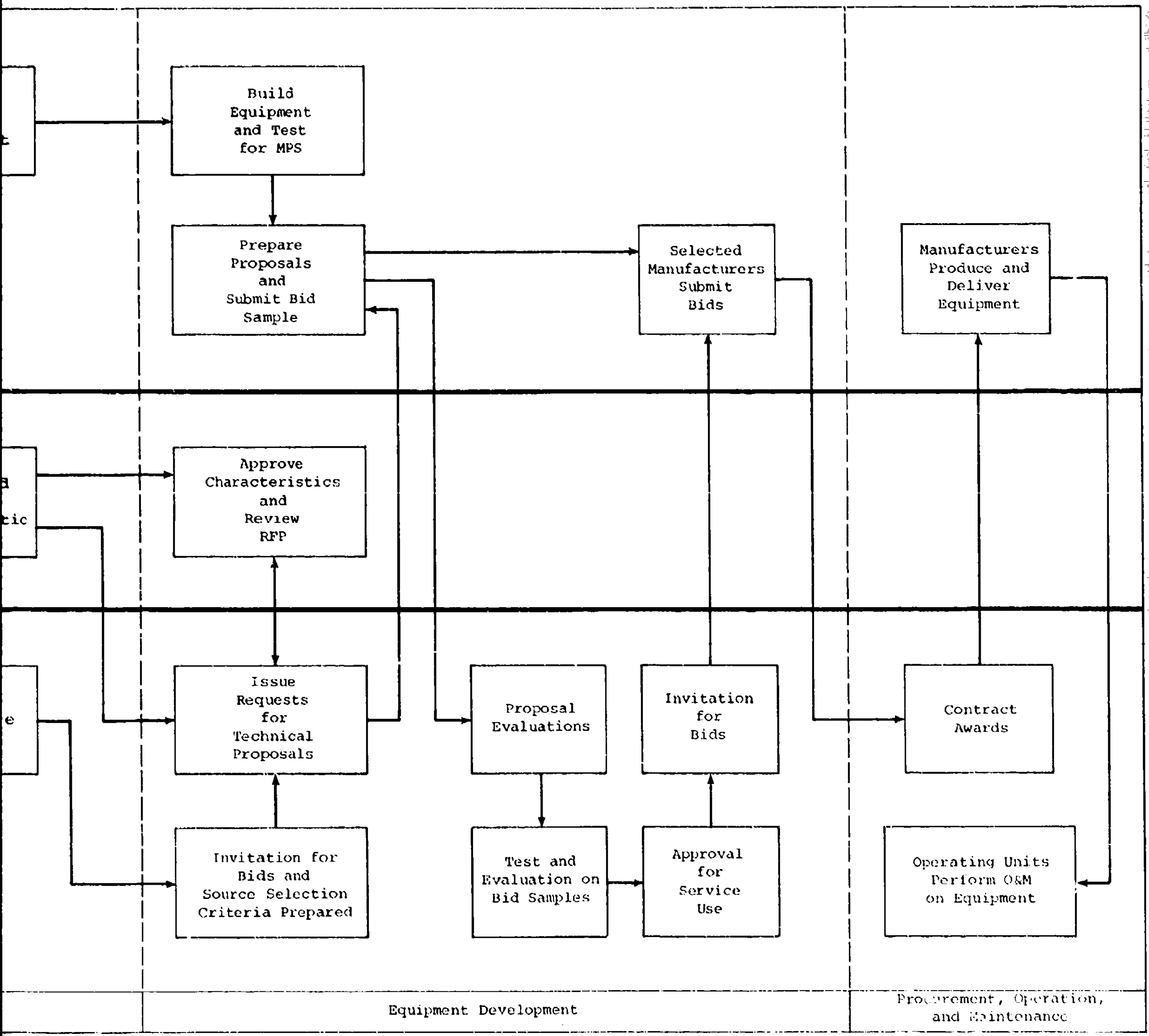


Figure 3-10. RECOMMENDED



RECOMMENDED ACQUISITION METHODOLOGY

3.4.1 Termination of Programs

The analysis of the current data link applications has not identified any on-going data link programs that should be terminated at this time. One reason for this situation is that certain data links have been specialized by incorporation of portions of the source and sink subsystem. This specialization renders the link difficult to incorporate in other applications, e.g., the AIDATS wide band data link includes certain processing functions that could be more logically implemented in the Side-Looking Airborne Radar (SLAR) source and sink subsystems. As a result, adaptation of the AIDATS data link to the function of another type of source/sink subsystem requires deletion of certain functions and the incorporation of others.

This comment is not meant as a criticism of the AIDATS program. It is used as an example because the AIDATS documentation made available to ARINC Research was the most detailed and definitive of those analyzed. The AIDATS program addressed its objectives in the manner that its program management considered to be most efficient. Therefore, as a matter of efficiency in implementing the system, certain source/sink processing functions were incorporated into the data link. However, a penalty must now be paid to use the AIDATS data link in a different application. Indications are that other data links also incorporate source and sink subsystem processing functions, although the available documentation does not include sufficient detail to make this determination.

Identification of on-going data link programs that could be terminated has not been made, although it is possible that one data link attaining production status could cause another to become a candidate for termination. For example, if either AIDATS or CEFLY LANCER were authorized to go into production for a specific application, substantial nonrecurring costs would have to be invested for such items as setting up the production line and to "productize" the equipment. Under these conditions, the next planned procurement of the competing non-production data link should be reviewed to determine if the production data link can be effectively used with no or minor modification. If it can be used, the need for investing additional production nonrecurring costs in the competing data link would thus be avoided. If future requirements forecast for the competing data link can be met by the production data link, the competing data link should be considered for termination at that time.

3.4.2 Consolidation of Data Links

Although no current data link programs have been identified as candidates for termination, certain near-term data link programs have been identified as candidates for consolidation with other current data link programs.

The developmental version of SOTAS used commercial equipment to implement the imagery data link requirement. This approach is not suitable for operational versions. The characteristics required of the imagery data link in the follow-on SOTAS have not been completely defined and the most suitable of the current data links cannot yet be selected. However, it appears that a wide band data link system having a high gain ground tracking antenna subsystem will meet the SOTAS imagery data link requirements. As such, the AIDATS, CEFLY LANCER wide band, ICNS wide band, and COMPASS BRIGHT data links are candidates for consolidation of the SOTAS imagery data link.

The PLSS command data link appears to be suitable for consolidation with JTIDS. The relatively modest bandwidth requirements of this link and the fact that a JTIDS terminal will probably be on the PLSS command aircraft favor the implementation of this link with JTIDS. It should be noted that the civil aviation community may object to placing PLSS in the L-band portion of the frequency spectrum since L-band is clearly allocated to radionavigation applications. This same comment is applicable to JTIDS itself, although there might be some basis for argument since JTIDS would potentially replace TACAN (radionavigation-system).

The PLSS glide bomb (GB) guidance data link has basically narrow bandwidth requirements. Its AJ margin is enhanced by the fact that directional antennas facing the command aircraft can be used. The equipment in the GB must be lightweight and expendable. Narrow-bandwidth data links that have these characteristics and should be considered for this application are: WALLEYE, WCCM, PMACS, GBU-15, and ICNS.

The PLSS sensor data link requires the wide band characteristics of an imagery or SIGINT system. However, multiple PLSS command aircraft must be served simultaneously, making difficult the implementation of a high-gain ground tracking antenna subsystem. The existing wide band data links that appear to be most suitable for consolidation of the PLSS sensor data link are: AIDATS, CEFLY LANCER, COMPASS BRIGHT, and ICNS (although some modifications to the ground tracking antenna subsystem may be required).

The RMCS command data link has basically narrow bandwidth requirements. In addition, a JTIDS terminal will probably be installed in the RMCS command aircraft. It would thus appear that JTIDS should be used to implement the RMCS command data link. However, the fact that the controlled vehicle requires a light weight (and possibly expendable) terminal dictates against the JTIDS because of its probable relatively high cost and large size. Therefore, the ICNS, PMACS, and WCCM narrow band data links should also be considered for use in this application.

The RMCS wide band data link requires a system having a high gain ground tracking antenna subsystem. Therefore, the AIDATS, CEFLY LANCER wide band, ICNS wide band, and COMPASS BRIGHT data links are all candidates for consolidation with the RMCS wide band data link.

The NOS wide band data link transmits infrared imagery from a sensor aircraft to a ground system. It requires a high gain ground tracking subsystem. Again, the AIDATS, CEFLY LANCER wide band, ICNS wide band, and COMPASS BRIGHT data links are all candidates for consolidation with the NOS wide band data link.

The GBU-15 command data link has basically narrow bandwidth requirements. The requirements for this data link appear to be very similar to those required by the WALLEYE II. As such, it appears that the narrow band data links for the GBU-15 and the WALLEYE II should be consolidated.

The near-term data links determined by ARINC Research as candidates for consolidation with current data links are summarized in Table 3-1.

Table 3-1. CANDIDATE NEAR-TERM DATA LINKS FOR CONSOLIDATION WITH CURRENT DATA LINKS

Candidate Data Links	Current Data Links
1. SOTAS Imagery	AIDATS CEFLY LANCER wide band ICNS wide band COMPASS BRIGHT
2. PLSS Command	JTIDS
3. PLSS GB Guidance	WCCM narrow band PMACS narrow band ICNS narrow band
4. PLSS Sensor	AIDATS CEFLY LANCER wide band ICNS wide band COMPASS BRIGHT
5. RMCS Command	JTIDS WCCM narrow band PMACS narrow band ICNS narrow band
6. RMCS Wide Band	AIDATS CEFLY LANCER wide band ICNS wide band COMPASS BRIGHT
7. NOS	AIDATS CEFLY LANCER wide band ICNS wide band COMPASS BRIGHT
8. GBU-15 Command	WALLEYE II narrow band

In addition to the possible data link consolidations discussed, there appears to be a limited amount of interoperability achievable between two data link systems, PLRS and JTIDS, if prompt action is taken. PLRS is basically less complex than JTIDS. However, both systems utilize the same TDMA approach with each unit in the TDMA net assigned one or more slots during an epoch. Both systems use different epoch lengths and time slots; and both incorporate frequency hopping (FH) of the RF carrier, although the PLRS FH capabilities are more limited than those of JTIDS. PLRS operates in the high UHF band while JTIDS operates at L band. PLRS has less communications and AJ processing capability than JTIDS, in order to preserve its lightweight low-cost goals. (For security reasons, the AJ capabilities will not be discussed here.)

In view of the above characteristics, it appears that JTIDS could, with relative ease, be designed to be "downward compatible" with PLRS. The design would address translation of the RF carrier frequency, conversion of epoch and slot lengths, and operation in a less sophisticated PLRS AJ mode. This capability would allow JTIDS-equipped aircraft to derive position location information from the PLRS net and return to the JTIDS net for communications when required. In addition, some commonality of hardware at the circuit board or module level may be achievable if the limited interoperability is made a requirement.

3.4.3 Standardization of Data Links

Standardization of extended data links is primarily achievable in far-term programs since near-term data links are normally limited to consolidations among existing programs. However, some near-term data link commonality appears to be feasible, particularly at the basic data link level, by implementing the approach discussed in Section 3.4.2.

No near-term data link programs have been identified as candidates for the development of F^3 specifications, even at the basic data link interface. However, several contractors have initiated in-house analyses of their data link equipment on the basis of the standard data link family concept, form-fit-function modular construction, state-of-the-art technical advances, and inclusion of anti-jam measures. ARINC Research Corporation's coordination with industry during this study resulted in identification of a modular growth concept that satisfies these aforementioned criteria. This concept embodies a lightweight, small volume, modular wide band data link that could be adapted to five existing or proposed data links and could be the basis for standardization in the near term. The proposed approach would use existing hardware, incorporate form-fit-function modular construction, and provide a modular growth capability. The advantage of the concept, and possible similar concepts from industry, would be the availability of a standard data link family one to two years earlier than could be obtained by the conventional method of first developing an F^3 characteristic in an open forum and then competitively procuring the equipment. Consequently, it is recommended that alternative industry approaches be investigated, the most promising approach selected, and a pilot program initiated, including the concurrent development of an F^3 characteristic. This would permit the near-term availability of a standard data link for a selected family.

Two far-term data link programs have been identified as candidates for the development of F^3 characteristics -- the Integrated Communications Navigation System (ICNS) being developed by the Army, and the Tactical Reconnaissance Data Link (TRDL) being developed by the Air Force. Since both of these data links appear to have multiple applications, the consideration of applying F^3 characteristics may be appropriate. Typical LRUs to which F^3 characteristics may be appropriate are included in the overall generic data link of Figure 3-2 and may include: signal conditioner, signal reconditioner, power amplifier, frequency synthesizer, control panels, antenna, etc. The development of such characteristics would ensure the compatibility of both systems with multiple platforms. In the event F^3 characteristics are prepared for both systems, and if both development programs are successful, the ICNS could become the DoD standard integrated (wide band/command and status) Expendable Data Link and the TRDL would become the DoD standard Wide Band Data Link.

3.5 EVALUATION OF FUTURE DATA LINK DEVELOPMENTS

New data links are expected to be introduced into the operating forces when new systems requiring the exchange of information by data link are developed. Consequently, the following discussion addresses the introduction of data links as part of new developmental systems. Any request to proceed with the independent development of a new data link should be treated by DoD as a special case and evaluated on its own merit, particularly with regard to anticipated future applications. If a new data link development is approved, it should conform to the requirements stated in Subsection 3.5.1.3.

It is anticipated that the new developmental systems will incorporate data links of the types shown in the families of Chapter Two, Figure 2-12. One or more of three approaches will be used:

(1) Utilize an unmodified existing data link

(2) Utilize a modified existing data link

(3) Incorporate a new data link (complete or partial)

Figure 3-11 indicates the approach for incorporating a data link in a new system.

3.5.1 Unmodified Existing Data Link

If it can be accomplished without adverse effect on the system, new developmental systems should use an existing data link (preferably MIL-qualified). Furthermore, systems using an existing data link should expect to receive DoD approval of the approach since commonality and possibly standardization will be achieved.

3.5.2 Modified Existing Data Link

If an unmodified existing data link cannot be practically incorporated in a newly developed system, a modified existing data link should be considered. Modified data links should normally be incorporated with a minimum of change. These modifications should be developed with consideration of the generic data link organization of Figures 3-2 through 3-8, to

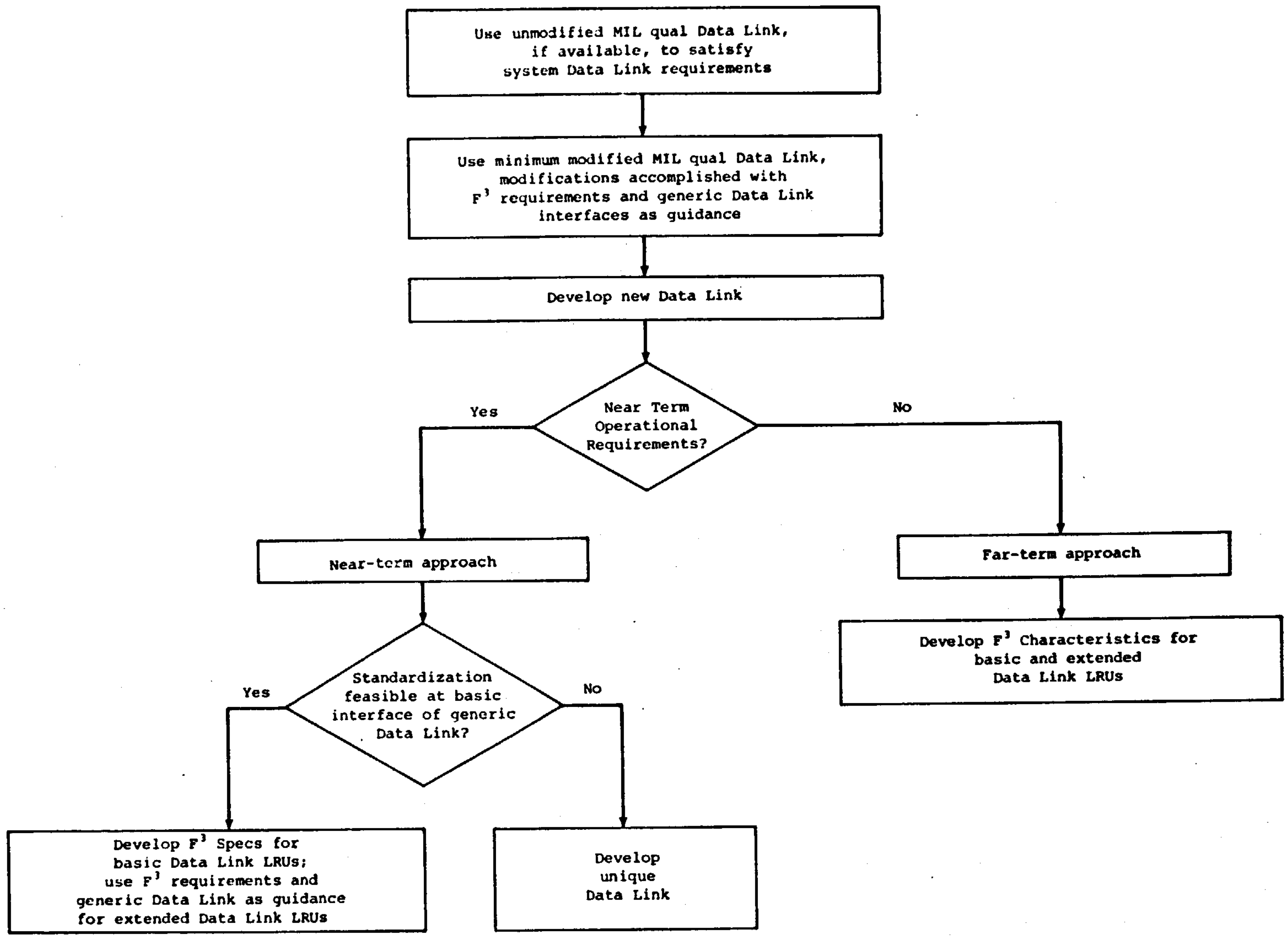


Figure 3-11. RECOMMENDED APPROACH TO IMPLEMENT DATA LINKS FOR NEW SYSTEMS

increase their possibility of use in future applications. Documentation of the modified links should establish that:

- The requirement for the modification is clearly identified
- The modification is a "minimum change"
- The modification has been designed with consideration of the generic data link organization of the appropriate family and the requirements of F^3 characteristics

3.5.3 New Data Link

If it has been determined that no existing data link or portions thereof, modified or unmodified, can meet the requirements of a new developmental system, a new data link, partial or complete, will be required. Prior to submittal of a new developmental system for DoD consideration of the data link approach, all potentially applicable data links must be identified and the reasons established why no existing data link, modified or unmodified, is suitable for incorporation in the system. In the event that a new data link is to be procured for a particular program, the program must be identified as near term or far term as defined in Chapter Two, Section 2.2.6.

3.5.3.1 Near-Term Program

If a near-term program requires the development of a new data link on a short time schedule, it should be determined if standardization is feasible at the basic data link interface.

If standardization can be achieved, and operational requirements permit, F^3 characteristics should be prepared for the basic data link interface and for all basic data link LRUs. In this case, the generic data link architecture would be used as guidance in defining the extended data link interface.

If standardization cannot be achieved, a unique data link must be developed. Programs using this approach can expect to receive intensive DoD review prior to (possible) approval, since commonality and standardization are not achieved by this approach.

3.5.3.2 Far-Term Program

A far-term program proposing the development of a new data link is one that has a schedule which includes the time required for the development of F^3 characteristics for all data link LRUs. In this case, standardization is normally achievable at the extended data link interface.

The standardization of a far-term data link should be implemented by the development of F^3 characteristics for all LRUs within the extended data link, in accordance with the appropriate generic data link block diagram. If successfully developed, this new data link may become the DoD standard for the family in which it is categorized. Programs using this approach should expect to receive DoD approval, provided an adequate justification for the non-use of an existing data link is presented.

3.6 ECONOMIC IMPACT OF STANDARDIZATION

The overall results of the economic analysis indicate that procurement of generic data links will result in substantial cost savings over the procurement of one-of-a-kind and limited quantities of distinct specialized data links. For example, the LCC of the wide band generic data link (800 airborne units and 150 ground units) was $342M, and the LCC of the summation of the non-standard wide band data links (800 airborne units and 150 ground units) was $512M. Thus, the potential cost savings associated with the wide band generic data link is $170M.

3.6.1 Analysis of Cost Categories

The constituent cost elements of the three major cost categories (RDT&E, Investment, and Operating and Support) were analyzed to determine the elements that contributed the most to potential cost savings by purchasing a wide band generic data link. The RDT&E cost category consists only of the in-house RDT&E costs. The investment cost category was subdivided into seven cost elements: purchase, initial spares, initial training, support equipment, first destination shipping, documentation, and inventory. The operating and support category was divided into eight cost elements: reorder spares, labor, materials, support equipment operation, maintenance transportation, recurring training, holding, and recurring inventory.

Table 3-2 presents an overview of the wide band generic data link LCC and a summation of the LCC of the non-standard wide band data links. The table shows that cost savings could be realized in all three of the major cost categories. The following subsections discuss the cost sub-elements that are most affected by procurement of a wide band generic data link.

3.6.1.1 RDT&E

The RDT&E cost represents the total expenditure required to develop a data link. Comparison of the RDT&E costs of the generic link and the summation of the RDT&E cost of the non-standard data links indicates a potential cost saving of $69.8M by using the standardization approach. This represents 41% of the total cost savings. These cost savings are due to a comparison of the estimated expenditures required to develop one generic data link and the expenditures (submitted by the Services) to develop the eleven non-standard wide band data links considered in this analysis.

3.6.1.2 Purchase

The purchase cost element represents the amount expended for procurement of complete data link sets. Comparison of the generic link with the summation of non-standard data links indicates a savings of $6M for the procurement of identical quantities of data links. The cost savings is attributed to (1) the estimated per-unit cost (obtained by analogy with comparable systems) of the generic link is slightly less than the average of the unit cost of the non-standard wide band links and (2) the effect of a larger production quantity for the generic data link.

Table 3-2. COMPARISON OF LIFE-CYCLE COSTS

Cost Element	Wide Band Generic Data Link, Air and Ground (Cost in $ M)	Summation of Non-Standard Individual Data Links, Air and Ground (Cost in $ M)	Cost Difference ($ M)	Percentage of Total Cost Difference
RDT&E	9	78.8	69.8	40.96
Investment	306.7	357.4	50.7	29.75
• Purchase	207.5	213.5	6.0	3.52
• Spares	94.8	121.2	26.4	15.49
• Training	0.014	0.1	0.086	0.05
• Support Equip.	1.8	11.3	9.5	5.60
• First Dest.	1.9	3.3	1.4	0.82
• Documentation	0.450	4.1	3.65	2.14
• Inventory	0.240	3.9	3.66	2.15
Operating & Support	26.2	76.1	49.9	29.28
• Reorder Spares	16.8	17.40	0.600	0.35
• Labor	0.563	0.66	0.097	0.06
• Materials	0.635	0.99	0.355	0.21
• Support Equip. Operation	0.584	4.00	3.416	2.00
• Maintenance Trans.	0.195	0.21	0.015	0.01
• Recurring Training	0.060	0.48	0.420	0.25
• Holding	6.800	40.40	33.600	19.70
• Recurring Inventory	0.576	12.00	11.424	6.70
Total	341.9	512.3	170.4	

3.6.1.3 Initial Spares

The initial spares cost element represents the expenditure for acquiring system and LRU investment spares for the organizational, intermediate, and depot maintenance levels. Comparison of the generic link with the summation of non-standard links indicates a savings of $26.4M (15.5% of the total cost savings). The cost savings is attributed to Economy of Scale considerations (producing more of one type of unit).

3.6.1.4 Initial Training

The initial training cost element represents the expenditure associated with schooling of personnel to operate and maintain the data links. Comparison of the generic data link with the non-standard wide band data links shows a savings of $86K. Although comparable numbers of personnel are required to operate and maintain the generic and non-standard wide band data links, the cost saving is attributed to the slightly greater MTBF of the generic data link and the rounding off effect when determining the number of personnel required to operate and maintain each type of data link (i.e., the model rounds off the number of personnel required to the next integer).

3.6.1.5 Support Equipment

The support equipment cost element represents the expenditure for procurement of additional support equipment at the intermediate and depot levels during the life cycle of the data link. Comparison of the generic data link cost element and the summation of the non-standard data links indicates a savings of $9.5M. The cost saving is attributed to the slightly higher MTBF of the generic data link and the rounding effect discussed in the previous paragraph.

3.6.1.6 First Destination Charges

The first destination charges represent the initial shipping costs for the data link equipments, investment spares, and support equipment. Comparison of the generic data link costs with the summation of the non-standard data link costs indicates a savings of $1.4M. The cost savings are attributable to the lesser cost of first-destination shipping charges because of lesser initial spares and support equipment requirements.

3.6.1.7 Documentation

The documentation cost element represents the one-time expense of associated documentation. Comparison of the generic data link costs with the summation of the non-standard data link costs indicates a savings of $3.65M, attributable to the requirement for one set of documentation for the generic data link compared with one set of documentation required for each of the non-standard wide band data links.

3.6.1.8 Inventory

This inventory cost element represents the one-time expense for the introduction of new items into the inventory. Comparison of the generic data link costs with the summation of the wide band data links shows a savings of $3.66M, attributable to the fewer new items introduced into the inventory from one generic data link compared to the number of items introduced for all of the non-standard data links.

3.6.1.9 Reorder Spares

The reorder spares cost element represents the expense of procuring additional spares to replace items lost through attrition. The cost of this element was comparable for the generic data link and the non-standard wide band data links since equivalent condemnation rates were used.

3.6.1.10 Labor

The labor cost element represents the expense of operating and maintaining the generic data link equipment at the operational, intermediate, and depot repair levels. This cost element was slightly less for the generic data link because of the smaller system MTBF of the non-standard wide band data links.

3.6.1.11 Materials

This materials cost element represents the expense associated with the piece parts consumed during repair of the LRUs at the intermediate and depot levels, plus the cost of items (such as light bulbs, fuses, wire, solder, etc.) that may be consumed at all three levels during corrective maintenance. This cost element was slightly less for the generic data link because of the smaller system MTBF of the non-standard wide band data links.

3.6.1.12 Support Equipment Operation

The support equipment cost element represents the expense associated with operating the different types of support equipment required at the intermediate and depot levels. Comparison of the costs associated with the generic data link support equipment operation and the costs of the non-standard wide band data links shows a cost savings of $3.4M. This is attributable to the lesser demand for support equipment required by the generic data link because of the slightly higher system MTBF of the generic data link.

3.6.1.13 Maintenance Transportation

The maintenance transportation cost element represents the costs associated with the two-way shipment for repair of failed systems and LRUs between the intermediate and depot levels, and the one-way replacement shipment of systems and LRUs that have been lost through attrition. Comparison of the costs associated with the maintenance transportation for the generic data link and the non-standard wide band data links showed that they were slightly lower for the generic data link. This is because of the slightly higher MTBF of the generic data link and the assumption of equal condemnation rates.

3.6.1.14 Recurring Training

The recurring training cost element accounts for the need to train additional operator and repair personnel each year as a result of expected annual personnel turnover rates. Comparison between the cost of the generic data link and the summation of the non-standard data links shows a cost saving of $420K. This is attributable to the lesser number of personnel required to operate and maintain the generic data link.

3.6.1.15 Holding

The holding cost element represents the cost of stocking various types of items at each repair level. Comparison between the cost of the generic data link and the non-standard wide band data links shows a cost savings of $33.6M. This savings is 19.7% of the overall cost savings; it is attributed to the reduced number of different types of items that have to be stocked at the organizational, intermediate, or depot levels.

3.6.1.16 Recurring Inventory

The recurring inventory cost element represents the management expense associated with keeping new items in the inventory. Comparison of the cost of the generic data link and the non-standard wide band data links shows a cost saving of $11.4M, attributable to the smaller quantity of items needed for a generic data link as compared with the quantity required for the eleven wide band data links used in this analysis.

3.6.2 Most Significant Cost Elements

The three cost elements that contributed the most to cost savings of the generic data link were the RDT&E, initial spares procurement, and the holding costs. The RDT&E cost saving was $69.8M (41%), initial spares procurement was $26.4M (15.5%), and the holding cost was $33.6M (19.7%).

Another comparison of LCC of the generic data link and the sum of wide band data links considered in this study is illustrated in Figure 3-12. This figure shows that in all of the major cost categories (RDT&E, Investment [Purchase & Other Investment], and Operation and Support) the LCC of the generic data link is less than the LCC of the sum of the wide band data links.

3.6.3 Sensitivity Analysis

An analysis was performed on the wide band generic data link to determine the sensitivity of the results obtained for variations of values of certain parameters. Although a number of parameters were

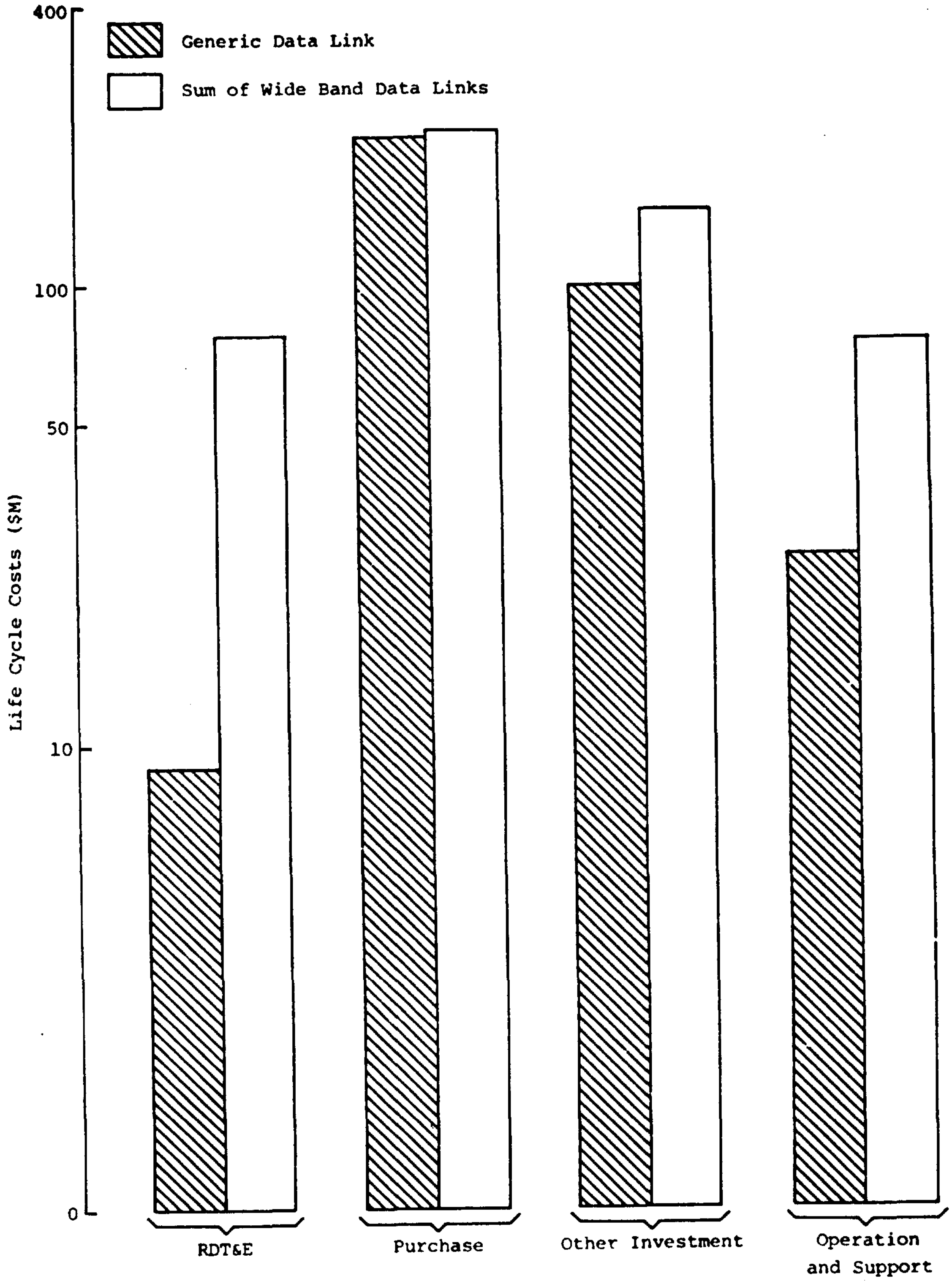


Figure 3-12. LIFE CYCLE COST VS SELECTED COST ELEMENTS

considered, only the system MTBF and the unit cost were examined in detail. These two parameters were selected because they directly impact almost all of the cost elements and there is a high degree of uncertainty of their value for the generic data link.

LCC as a function of system MTBF for the generic data link (air and ground) is shown in Figures 3-13 and 3-14. For an assumed baseline system MTBF of 500 hours for the airborne terminal of the data links, the LCC of the sum of the wide band data links (air) (ΣNS_A) was $239M. For the same system MTBF, the generic data link (air) LCC was $187M. As illustrated in Figure 3-15, the assumed MTBF for the generic data link (air) could be in error by a factor of 4 (MTBF decrease from 500 to 125 hours) before the LCC of the generic data link (air) and the sum of the wide band links would be the same.

For an assumed baseline system MTBF of 400 hours for the ground and shipboard terminals of the data links, the LCC of the sum of the wide band data link (ground/shipboard) (ΣNS_G) was $263M. For the same system MTBF, the generic data link (ground/shipboard) LCC was $153M. As shown in Figure 3-14, the assumed MTBF for the generic data link (ground/shipboard) could be in error by a factor of four (MTBF decrease from 400 to 100 hours) before the LCC of the generic data link (ground/shipboard) and the sum of the wide band links (ground/shipboard) would be the same.

In both cases, the assumed system MTBF would have to be in error by more than a factor of four before the LCC of the generic data link was greater than the LCC of the sum of the non-standard wide band data links.

Life-cycle cost as a function of unit cost for the generic data link (air and ground) is shown in Figures 3-15 and 3-16. The assumed baseline unit cost for the generic data link (air) was $175,000 and for the generic data link (ground/shipboard) was $450,000. These baseline costs were based on the average cost of the wide band data links used in this analysis. The respective LCCs are $187M and $153M. The LCC of the sum of the wide band data links (air) (ΣNS_A) is $239M and for the wide band data links (ground/shipboard) (ΣNS_G) is $263M. The figures show that the assumed unit cost for the generic data link (air) could be in error by 26 percent and the assumed unit cost for the generic data link (ground/shipboard) could be in error by 78 percent before the LCCs of the generic data link and the sum of the wide band links would be equal.

The overall economic analysis indicates that there is a potential economic advantage to the generic data link as compared with the sum of the non-standard wide band data links. Furthermore, the sensitivity analysis shows that this conclusion is generally insensitive to variations to the estimated MTBF and unit cost over a comparatively wide range.

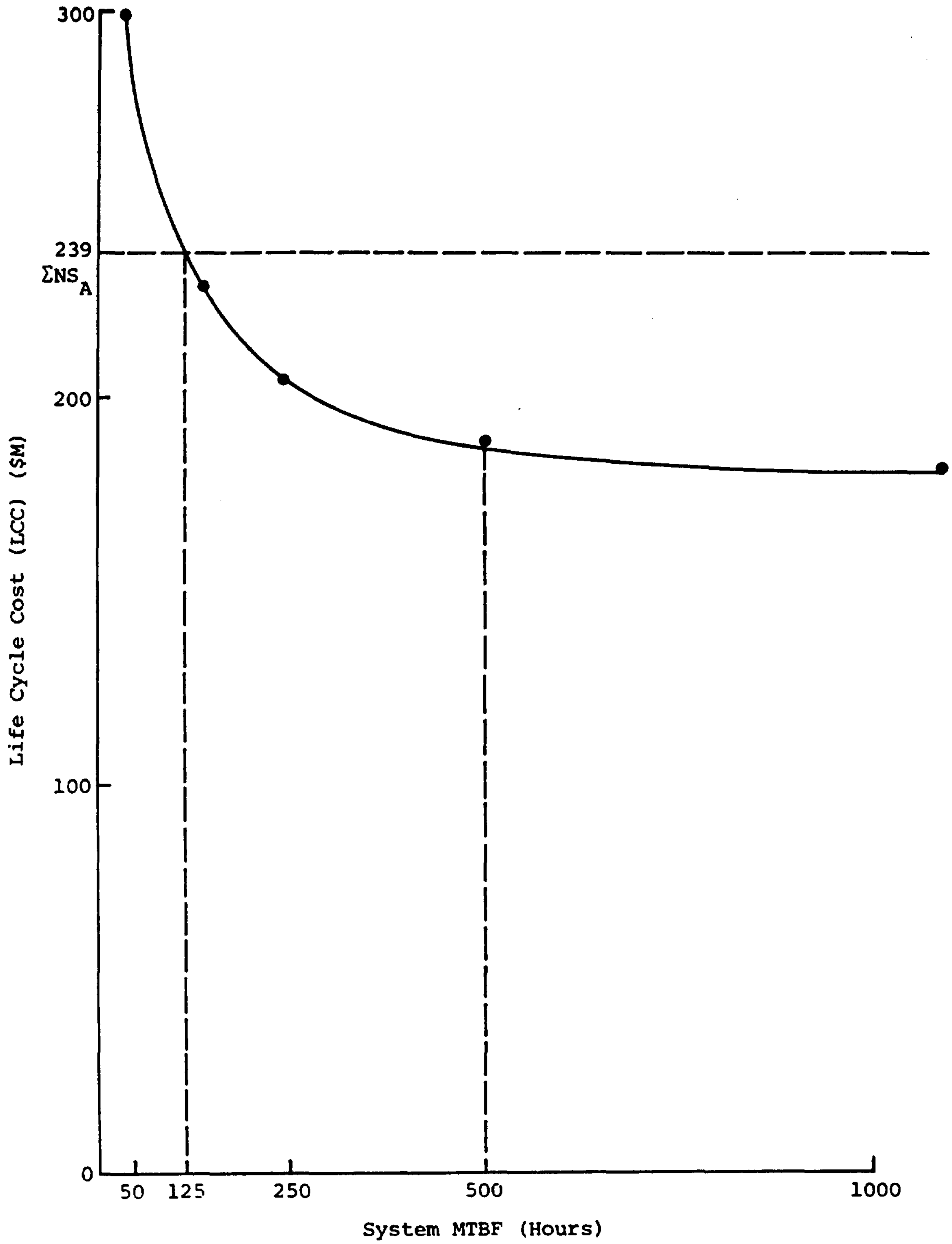


Figure 3-13. WIDE BAND GENERIC DATA LINK (AIR) LIFE CYCLE COST VS SYSTEM MTBF

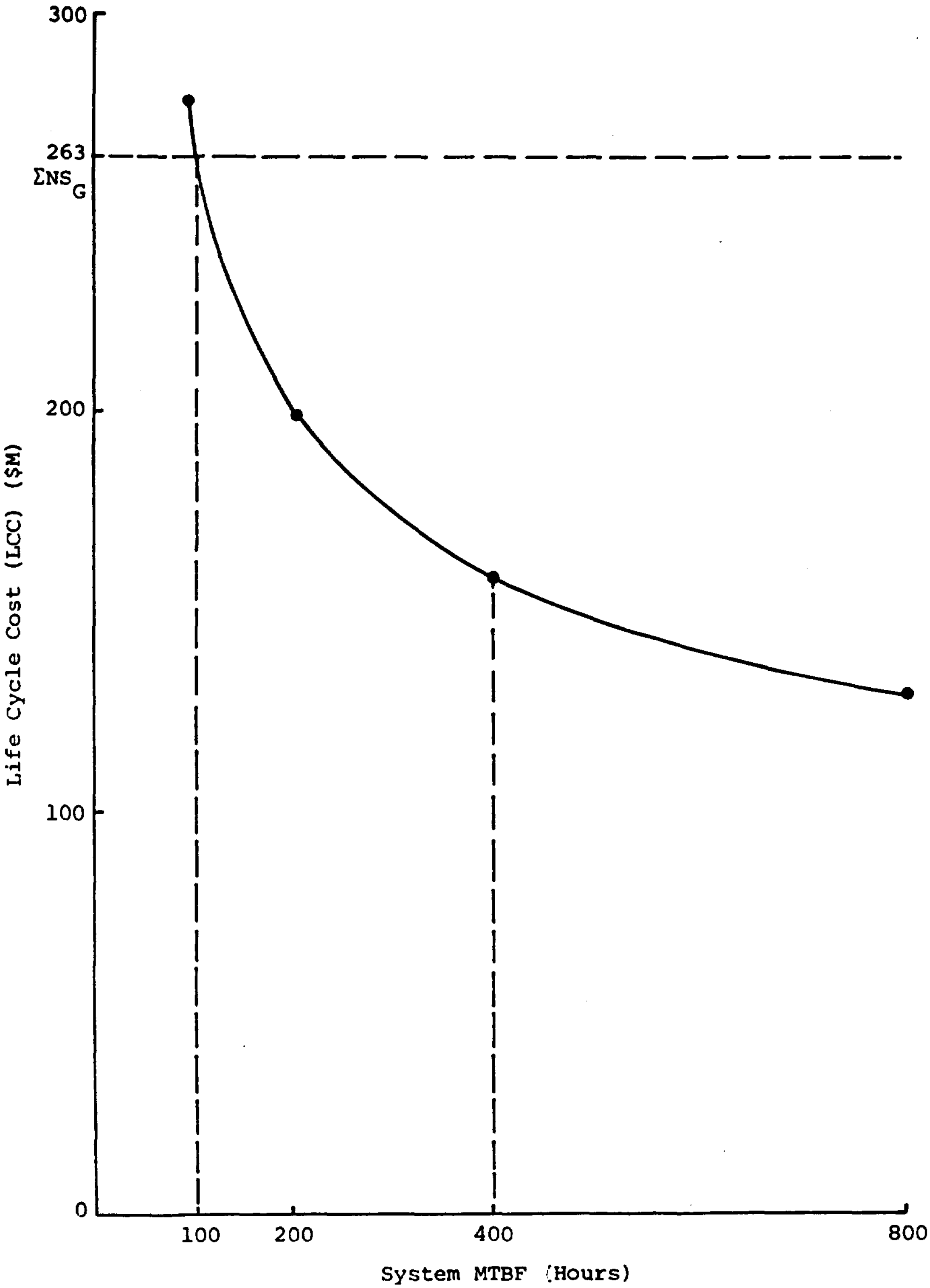


Figure 3-14. WIDE BAND GENERIC DATA LINK (GROUND AND SHIPBOARD) LIFE CYCLE COST VS SYSTEM MTBF

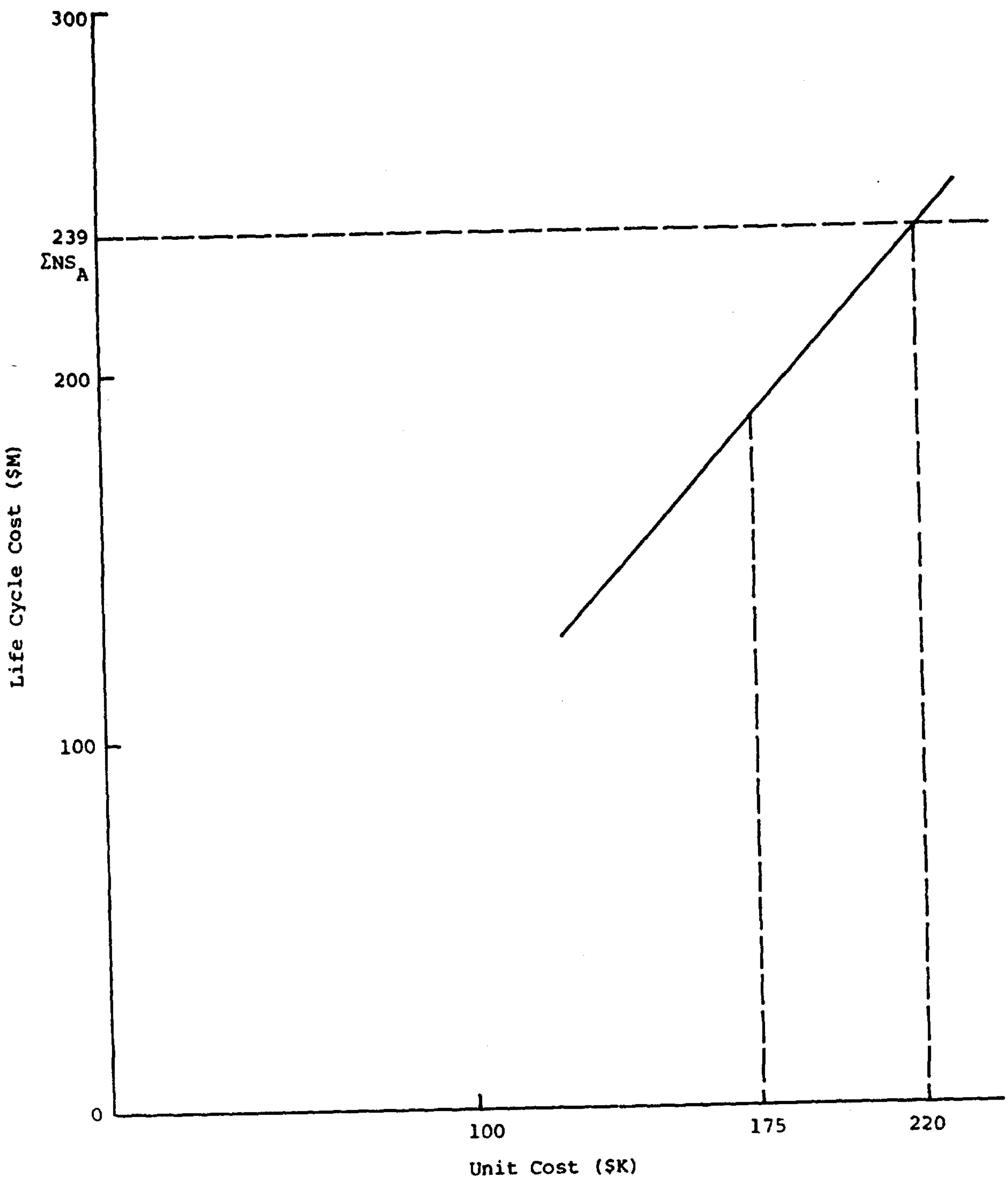


Figure 3-15. WIDE BAND GENERIC DATA LINK (AIR) LIFE CYCLE COST VS UNIT COST

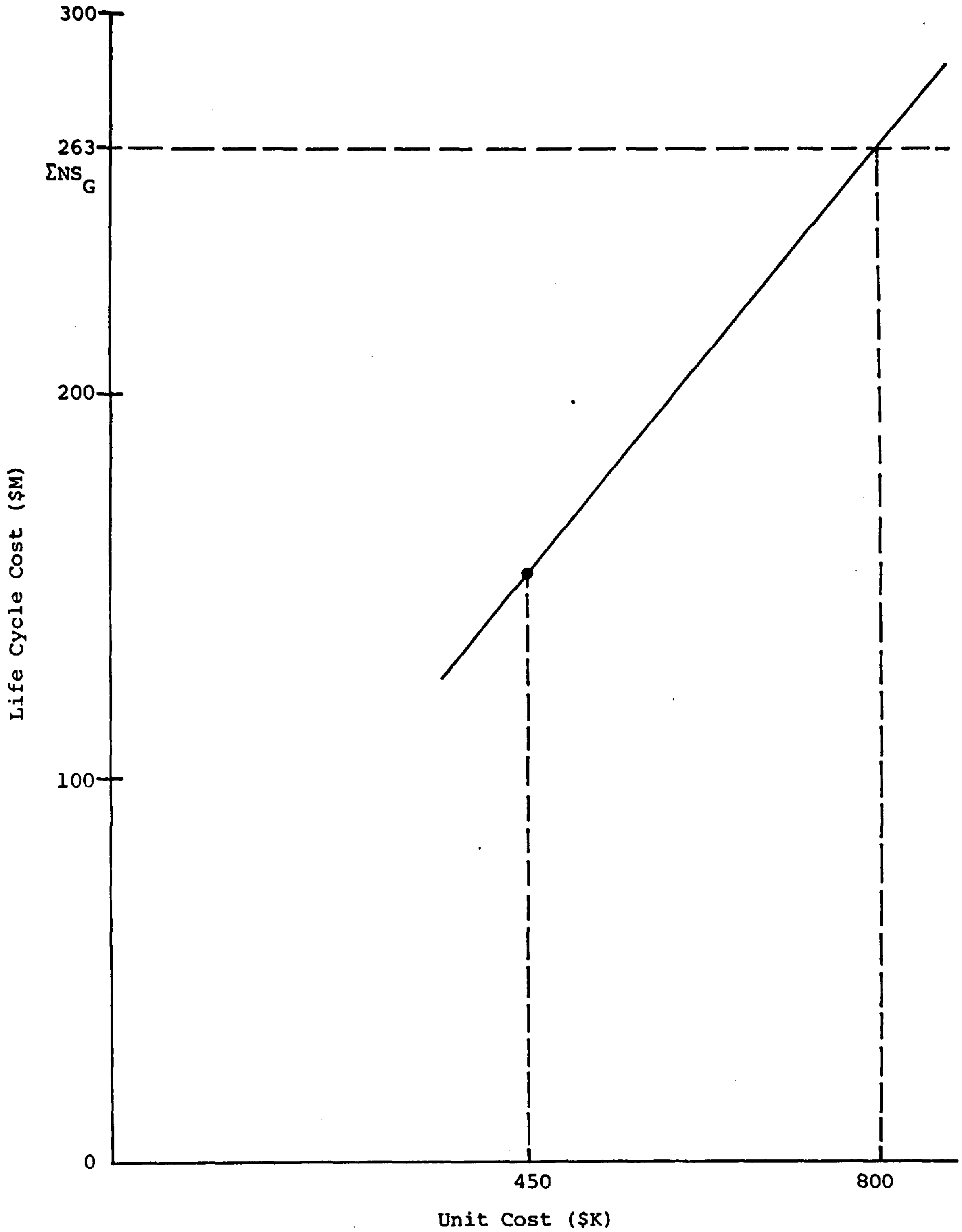


Figure 3-16. WIDE BAND GENERIC DATA LINK (GROUND AND SHIPBOARD) LIFE CYCLE COST VS UNIT COST

CHAPTER FOUR

CONCLUSIONS AND RECOMMENDATIONS

4.1 GENERAL DISCUSSION

The purpose of this section is to discuss the general conclusions and recommendations that evolved from the study.

Analysis of the data links indicated that they could be characterized by a limited number of descriptors. Quantification and analysis of the descriptors resulted in a clustering of the data links; it also provided the basis for the initial grouping of data links and subsequent formation of data link families. Six data link families were identified that (1) represent the consolidation of the numerous individual data links now under development and (2) could provide the basis for data link standardization in the future. The six data link families cover the broad frequency spectrum requirements of DoD tactical links from HF systems through electro-optical systems. The architecture of each data link family was defined to a level of detail sufficient to allow assessment of the applicability of F^3 type characteristics to data link procurement. This assessment indicated that F^3 characteristics could be applied to the development of data links or their LRUs.

In assessing the potential for standardizing data links, based on the family structure that was developed, two approaches evolved: (1) the near-term approach and (2) the far-term approach. The near-term approach recognized that standardization was not possible with existing links and concentrated on analyzing existing programs to determine ways of reducing proliferation, such as termination or consolidation of programs. The far-term approach analyzed the status of far-term programs to identify candidates for development and application of F^3 characteristics to the generic data links associated with each family to provide the basis for future data link standardization. The purpose of developing a generic data link for data link families was to determine if a single defined data link could be compatible with the characteristics of all of the data links within the family. Since the generic data link was all encompassing, it did not necessarily match the specific technical characteristics of each of the associated data link systems. Consequently, for each family generic data link, it was necessary to develop options that would permit it to be directly responsive to the specific characteristics of the links within that family. The result was a modular growth data link that was compatible with the characteristics of the data links within a family.

The generic data link was further subdivided into two categories: (1) basic data link and (2) extended data link. The basic data link includes the data modulator, the data demodulator, RF portions of the system (including antennas), and controls necessary for the operation of the basic data link. The extended data link includes the basic data link functions as well as those of the signal conditioner and signal reconditioner. Options available to the basic data link include the antenna, power amplifier, antenna interface, frequency synthesizer, operator control/indicator, RF transmitter, and RF receiver. Options available to the extended data link, in addition to those of the basic data link, include EDAC, CRYPTO, and AJ data coding and decoding.

To determine the potential benefits of the generic approach to data link standardization, an economic analysis was performed on one of the selected families (wide band). The overall results of this analysis indicated that the generic data links could potentially result in substantial life-cycle-cost savings over the cumulative costs of the constituent family members.

As a result of this study and several related efforts conducted under the auspices of the Department of Defense, the basis for an effective program to reduce data link proliferation in the near-term and effect data link standardization in the far-term has been established. However, to realize this potential, an extraordinary management approach will be necessary. It is critical that an Executive Agent for all DoD data link programs be chartered as soon as possible to be responsible for continuing the current standardization effort. The Executive Agent should have the authority to conduct the necessary detailed investigations of the recommended near-term data link program consolidations, as well as to prepare and implement a plan for far-term data link standardization. To ensure success, the Executive Agent should be responsive to the requirements of all of the Services while being responsible to a single office in DoD. The Executive Agent's staff should include representatives from each Service who are able to devote a significant portion of their time to implementing the organization's charter. Ultimately, each of the six standard data link families should be organized as separate offices under direction of the Exectuive Agent. These separate offices would be responsible for controlling the research, development, and acquisition of their respective standard families.

The Executive Agent must have the power to ensure that individual Service weapons acquisition managers separately identify the costs of required data links from the costs of other elements of their respective systems. Also, the managers must submit their data link requirements to the Executive Agent for review and concurrence, following the pattern and in agreement with the Service or DoD level Review Council milestones.

Certain areas not within the scope of the study should be addressed if standardization of data links is to become a reality. Most significant is potential standardization at the module level within the LRUs to reduce the quantity of different types of modules in the inventory. The study did not investigate standardization below the LRU level. It is recognized that there may be potential commonality among data links below this level (e.g., a common frequency synthesizer) and this could represent an area for future investigation to determine if the potential can be realized. Although one of the conclusions of the Electronics-X study was that standardization was not cost effective below the LRU level, technology advances during the past 4 to 5 years (e.g., development of LSI and VLSI) make further investigation necessary. Since the economic analysis was performed only on the wide band data links, and with gross estimates of costs, it appears that continued use of the existing LCCM would greatly aid in evaluating the cost savings (due to standardization) as refined cost data becomes available. A detailed examination should be conducted of the partitioning of processor functions, in order to separate the data link from the functions that should be performed by the source or sink subsystems.

During the study, other areas of the overall communications standardization problems were detected that indicate additional study is required for a detailed understanding of the problem. These include: (1) incorporation of voice communications and other non-formatted signals within the defined family structure; (2) definition of AJ standards and specifications: and (3) definition and examination of interoperability of data links. A detailed implementation plan should be developed to pursue these additional tasks.

4.2 SPECIFIC CONCLUSIONS

- Data links have not been recognized as a significant category of electronic equipment
- The data links considered in this study can be categorized into six data link families (HF, Low Data Rate, TDMA/Multiple User, Wide Band, Integrated Sensor, and Electro-Optical).
- Each of the six data link families can be represented by a modular growth generic data link.
- A generic data link for each of the data link families can be developed that will satisfy the characteristics of all of the data links within each family.
- Each generic data link should consist of a "basic data link" and an "extended data link".
- A near-term approach is required to reduce data link proliferation by consolidating near-term programs and by imposing the requirement that every effort be made to utilize existing data links to meet a new requirement. Certain near-term data link programs have been identified as candidates for consolidation with other current data link programs (see Chapter Three, Section 3.4.2).

- Analysis of current data links has not identified any totally duplicative on-going data link programs that should be terminated at this time.
- A far-term approach is required for data link standardization to allow sufficient time to initiate the development of F^3 characteristics that could be applied to many of the generic data links of their LRUs.
- No near-term data link programs have been identified for the development of F^3 characteristics. However, a parallel program of data link hardware and F^3 characteristic development could be initiated to shorten the time period required to produce a data link to F^3 characteristics.
- Two far-term data link programs (ICNS and TRDL) have been identified as possible candidates for the development of F^3 characteristics. Because both of these data links appear to have multiple applications, the consideration of applying F^3 characteristics appears appropriate. The development of such characteristics would ensure the compatibility of both systems with multiple platforms.
- A limited amount of interoperability between JTIDS and PLRS is achievable if prompt action is taken. It appears that JTIDS could be designed, with relative ease, to be "downward compatible" with PLRS by translation of the RF carrier frequency, conversion of the epoch and slot lengths, and by operating in the less sophisticated PLRS AJ mode.
- The overall results of the economic analysis indicate that generic data links could result in substantial life-cycle-cost savings over the corresponding non-standard data links.
- No organization exists with the authority to control the development and acquisition of data links.

4.3 SPECIFIC RECOMMENDATIONS

- Data links should be recognized as a significant Category of electronic equipment.
- It is recommended that the concept of generic modular growth data links be implemented to standardize future data links. F^3 characteristics should be developed on the ICNS or TRDL program as the initial step in evolving standard data link family(s).
- Detailed studies should be conducted of the potential candidate data links for consolidation (see Section 3.4.2) to determine if consolidations can be implemented.
- An investigation should be initiated to examine the possible standardization at the module level within the LRUs of the generic data links.

- An investigation should be initiated to evaluate the possibility of implementing a standard partitioning of processor functions between the data link and the source/sink subsystems.
- An Executive Agent should be chartered to act as the focal point for the development and acquisition of all DoD data links. The Executive Agent should have the authority to conduct the necessary detailed investigations of the recommended near-term data link program consolidations and to plan and implement far-term data links standardization.
- Cost goals and program milestones for data links associated with major weapon systems should be established and monitored independently of the weapon systems.
- The LCCM should be used to evaluate the life-cycle costs of other data link families and refine the life-cycle-cost analyses as more accurate cost data becomes available.
- The potential requirement for limited inter-operability between JTIDS and PLRS should be investigated.
- A pilot program to develop a generic data link in the near term should be initiated.

APPENDIX A

EXAMPLE OF APPLICATION OF DATA LINK GROUPING METHODOLOGY

1. GENERAL

This appendix presents an example of the application of the methodology used to group the data links within selected partitions. The partition selected for this example is that of the Medium-Power Narrow-Bandwidth. The analysis consisted of (1) development of the descriptor matrix consisting of all of the data links contained within the selected partition, (2) development of the commonality matrix, (3) analysis of the descriptor matrix and the commonality matrix, and (4) development of data link groupings within the selected partition.

2. DEVELOPMENT OF THE DESCRIPTOR MATRIX FOR THE MEDIUM-POWER NARROW-BANDWIDTH PARTITION

Development of the descriptor matrix consisted of generating a coding key (Figure A-1) for the 13 input data descriptors used to describe each of the data links, and then describing each data link by means of the descriptor numerics contained in the coding key. When all of the data links were codified, the resulting list was stored in a computer for subsequent use in developing the descriptor and commonality matrices.

The descriptor matrix consists of the list of data link systems contained in the Medium-Power Narrow-Bandwidth partition and ten associated descriptors obtained from the input data descriptors. Eight of the ten descriptors are the same as the input descriptors; two descriptors -- PI and Number of Users -- were created from five of the basic input descriptors:

$$\text{PI (Probability of Intercept Index)} = \frac{\text{Beam Width} \times \text{Power}}{\text{RF Bandwidth}} \times 10^3 \text{ and}$$

$$\text{Number of Users} = \text{Number of Channels} \times \text{Users/Channel}$$

Both of these composite descriptors were used for relative comparisons among the data link systems. A low value of PI indicates a relatively low probability of intercept in comparison with the other data links in the partition. A very high value of USERS indicates that the data link is most likely a TDMA data link (e.g., JTIDS USERS = 1000). Figure A-2 is the resulting descriptor matrix for the Medium-Power Narrow-Bandwidth partition.

TYPE	INFO BW	AJ	BEAM WIDTH	CRYPTO	FREQ SPECTRUM	RANGE	FROM	TO	N CHAN	PWR	USERS/CHAN	RFBW
Undefined Unknown	Undefined Unknown	Undefined Unknown 0	Undefined Unknown 0	Undefined Unknown 0	Undefined Unknown 0	Undefined Unknown 0	Undefined Unknown 0	Undefined Unknown 0	Undefined Unknown 0	Undefined Unknown	Undefined Unknown 0	Undefined Unknown 0
Analog 2	Absolute Value in KHz	No Reqmt 2	Absolute Value in degrees	No Reqmt 2	A Band 2 (0-250MHz)	Absolute Value in KM	Gnd,Fixed 2	Gnd,Fixed 2	Number of Channels	Absolute Value in W	Number of Users per Channel	Absolute Value in KHz
Digital 3		Absolute value in db		Yes 3	B Band 3 (250-500MHz)		Gnd,Trans 3	Gnd,Trans 3				
Other 4					C Band 4 (500-1000MHz)		Ship,Sub 4	Ship,Sub 4				
					D Band 5 (1-2GHz)		Ship,Surf 5	Ship,Surf 5				
					E Band 6 (2-3GHz)		Gnd, Vehicle 6	Gnd, Vehicle 6				
					F Band 7 (3-4GHz)		Aircraft 7	Aircraft 7				
					G Band 8 (4-6GHz)		Missile 8	Missile 8				
					H Band 9 (6-8GHz)		Gnd,Man 9	Gnd,Man 9				
					I Band 10 (8-10 GHz)		Satellite 10	Satellite 10				
					J Band 11 (10-20GHz)		Balloon 11	Balloon 11				
					K Band 12 (20-40GHz)							
					L Band 13 (40-60GHz)							
					M Band 14 (60-100GHz)							

Figure A-1. DESCRIPTOR PARAMETER CODING KEY

TYPE	BW	A/J	P/I	CRYPT	FREQ	RANGE	FROM	TO	USERS
3	1		2101	3	2	30	3	3	1
3	18		2101	3	2	30	3	3	1
3	18		2101	3	2	30	3	3	1
3	4		36001	3	8	450	7	3	24
3	13		7693	3	10	370	3	7	1
3	2		3150001	2	2	32	3	3	2
3	2		3150001	2	2	32	3	3	2
3	4		180001	3	4	32	3	3	1
3	5		72001	3	2	556	3	10	1
3	4		720001	2	2	185	7	3	1
3	16		90001	3	3	180	3	7	1
3	16		90001	3	3	180	3	7	1
3	1		29	2	11	185	7	8	10
3	10		2400	3	9	556	3	10	1
3	10		2400	3	2	556	10	5	1
3	29		3600	3	5	556	3	7	1000
3	2		2334	3	2	32	3	3	24
3	2		2334	3	2	150	3	7	24
3	5		72001	3	2	556	10	7	50
3	48		3600	3	3	32	3	9	275
3	48		3600	3	3	185	3	7	95
3	13		271	3	2	50	7	3	3
3	2		9000001	3	3	93	3	3	7
3	3		720001	2	3	15	3	3	26
3	16		28126	3	3	40	3	3	3
3	16		28126	3	3	40	3	3	3
3	1		2400	2	5	370	7	8	4
3	2		3150001	3	2	32	3	3	7
3	4		247	2	5	93	7	8	5
3	10		3201	2	8	370	7	8	8

Figure A-2. **MEDIUM-POWER NARROW-BANDWIDTH PARTITION DESCRIPTOR MATRIX**

3. DEVELOPMENT OF THE COMMONALITY MATRIX

The commonality matrix was developed, based on assessment criteria, to compare the descriptor values of each of the data links within a partition to obtain an indication of commonality. The commonality assessment criteria (Figure A-3) consist of ten descriptors and the criteria that must be met by a "Compared" system when compared with a "Reference" system. Each system, in turn, was made the reference system and all other systems within the partition were compared with it, descriptor by descriptor. For commonality, two of the descriptors, Type and Frequency Spectrum, had to be matched completely. The Intercept Probability descriptor of the Compared system had to be equal to or greater than the Referenced system for compatibility. The remaining descriptors of the Compared systems had to be equal to or greater than the Reference system.

Descriptor	Criterion*
Type (T)	$T_i = T_j$
Information Bandwidth (B)	$B_i \geq B_j$
Anti-Jam Capability (AJ)	$AJ_i \geq AJ_j$
Intercept Probability (I)	$I_i \leq I_j$
Encryption (E)	$E_i \leq E_j$
Frequency Spectrum (F)	$F_i = F_j$
Range (R)	$R_i \geq R_j$
From Unit (FU)	$FU_i \geq FU_j$
To Unit (TU)	$TU_i \geq TU_j$
Number of Users (N)	$N_i \geq N_j$
*i = Reference system; j = Compared system	

Figure A-3. COMMONALITY ASSESSMENT CRITERIA

These criteria were applied to the descriptor matrix by a small computer program. The results of the assessment program for the Medium-Power Narrow-Bandwidth partition are shown in Figure A-4.

FUNCTIONAL AREA FILE NAME? MPNBW1

TYPE	BW	A/J	P/I	CRYPT	FREQ	RANGE	FROM	TO	USERS	AVE
1.000	.069	.759	.897	1.000	.414	.103	.690	.483	.345	.576
1.000	.897	.759	.897	1.000	.414	.103	.690	.483	.345	.659
1.000	.897	.759	.897	1.000	.414	.103	.690	.483	.345	.659
1.000	.448	.586	.379	1.000	.034	.828	.931	.483	.828	.652
1.000	.690	.586	.483	1.000	0.	.793	.690	.759	.345	.634
1.000	.276	.586	.103	.241	.414	.310	.690	.483	.414	.452
1.000	.276	.586	.103	.241	.414	.310	.690	.483	.414	.452
1.000	.448	.586	.207	1.000	0.	.310	.690	.483	.345	.507
1.000	.517	.966	.345	1.000	.414	1.000	.690	1.000	.345	.728
1.000	.448	.586	.172	.241	.414	.690	.931	.483	.345	.531
1.000	.828	.586	.276	1.000	.241	.586	.690	.759	.345	.631
1.000	.828	.586	.276	1.000	.241	.586	.690	.759	.345	.631
1.000	.069	.586	1.000	.241	0.	.690	.931	.897	.724	.614
1.000	.621	.897	.724	1.000	0.	1.000	.690	1.000	.345	.728
1.000	.621	.897	.724	1.000	.414	1.000	1.000	.517	.345	.752
1.000	.931	1.000	.586	1.000	.069	1.000	.690	.759	1.000	.803
1.000	.276	.586	.793	1.000	.414	.310	.690	.483	.828	.638
1.000	.276	.586	.793	1.000	.414	.517	.690	.759	.828	.686
1.000	.517	.966	.345	1.000	.414	1.000	1.000	.759	.897	.790
1.000	1.000	.897	.586	1.000	.241	.310	.690	.931	.966	.762
1.000	1.000	.897	.586	1.000	.241	.690	.690	.759	.931	.779
1.000	.690	.586	.931	1.000	.414	.414	.931	.483	.517	.697
1.000	.276	.621	0.	1.000	.241	.483	.690	.483	.655	.545
1.000	.310	.655	.172	.241	.241	0.	.690	.483	.862	.466
1.000	.828	.586	.448	1.000	.241	.379	.690	.483	.517	.617
1.000	.828	.586	.448	1.000	.241	.379	.690	.483	.517	.617
1.000	.069	.586	.724	.241	.069	.793	.931	.897	.552	.586
1.000	.276	.586	.103	1.000	.414	.310	.690	.483	.655	.552
1.000	.448	.586	.966	.241	.069	.483	.931	.897	.586	.621
1.000	.621	.586	.621	.241	.034	.793	.931	.897	.690	.641
1.000	.543	.687	.520	.798	.253	.543	.767	.653	.572	

Figure A-4. MEDIUM-POWER NARROW-BANDWIDTH PARTITION COMMONALITY MATRIX

The commonality matrix consists of a list of data link systems within a partition and a relative comparison of each of the descriptors of the data link systems with descriptors of all of the other data link systems within the partition. For example, the BW descriptor of 29 of the systems was compared with the BW descriptor of the first system listed. Two of the other systems met the criteria, while 27 did not. Therefore, the entry of 0.069 was obtained by dividing 2/29. This process was reiterated for each of the 30 links, comparing each of the ten descriptors, then averaging across the descriptors for each data link to obtain the average value of each of the descriptors. For example, the average of the descriptor values for the first system listed is 0.576. This value was obtained by

$$\sum_{N=1}^{10} \text{Descriptors} \div 10$$

The average, over all the systems, of descriptor commonality was obtained by

$$\sum_{N=1}^{30} \text{each descriptor value} \div 30$$

For the BW descriptor this was 16.279 $\div$ 30 = 0.543.

In summary, the values under the descriptor columns are the percent of all other systems within the partition which could be satisfied by the descriptor of the reference system. The values in the extreme right column are the average overall descriptor percentages for each of the data link systems within the partition. The last line on the figure is the average, over all systems, of descriptor commonality percentages.

4. ANALYSIS OF THE DESCRIPTOR MATRIX AND THE COMMONALITY MATRIX

The Descriptor Matrix and the Commonality Matrix were examined in detail to assess the commonality of the data links within a partition and to group the data links into sets that could be refined to decrease the quantity of data links, permitting consolidation and subsequent development of the data link families.

Initially the commonality matrix was inspected and listed from the highest commonality average index to the lowest commonality average index to determine whether there were any obvious break points that would allow initial groupings of data links. The inspection revealed that the JTIDS had the highest commonality with the other data links and the descriptor that caused the most lack of commonality was the frequency band. It also indicated that systems 2 and 3 were identical, as were 6 and 7, 9 and 19, 11 and 12, and 25 and 26.

Analysis of the descriptor matrix revealed that there existed certain data links with unique features; i.e., the satellite links, the glide bomb and missile links, and the PLRS links that contained a comparatively high data rate with respect to the other data links in the partition.

5. DEVELOPMENT OF DATA LINK GROUPINGS WITHIN THE SELECTED PARTITION

Analysis of the Descriptor Matrix and Commonality Matrix led to the separation of the 30 data links into five groups including (1) the satellite links, (2) the missile and condor links, (3) the PLRS, because of its relatively high data rate, and (4) and (5) the two distinct sets of the IBWs (information bandwidths). After the first three groups were established, the IBWs of the remaining data links were examined. The IBWs broke into two distinct sets: (1) Consisted of ten data links with IBW of <4kHz and (2) consisted of nine data links with IBW of 13-29kHz. These last two sets made up the remaining groups within the Medium Power-Narrow Bandwidth partition.

Figure A-5 illustrates the complete breakdown of the 66 data links into the initial partitioning of 27 groupings.

LP/NB				MP/NB					HP/NB		
A	B	C	D	E	F	G	H	I	J	K	L
GRA-114 (Sound) GRA-114 (CMD) PEMS [illegible]	ANQ-23	TACFIRE FO-FDC	AGTELIS OS-CP	AFSATCOM Uplk AFSATCOM Dnlk FLTSATCOM Uplk FLTSATCOM Dnlk	AGTELIS CP to MULTEWS (G) COMPASS EARS TPQ-36 TPQ-37 TSQ-73 ASAP Survivor MULTEWS (G-G) Uplk MULTEWS (G-A) Uplk SAM-D Inter SAM-D Intra TACFIRE FDC-BDU	JTIDS AGTELIS CPC to CAC AGTELIS CP to CPC CEFLY LANCER (NB) Uplk CEFLY LANCER (NB) Dnlk QUICKLOOK II TACELIS Uplk TACELIS Dnlk COMPASS BRIGHT Uplk	CONDOR CMD MGGB/EOGB CMD WALLEYE (D) CMD JSOR CMD	PLRS Manpack PLRS A/C	SETAD	CEFIRM LDR Uplk	PLSS Control

LP/WB		MP/WB			HP/WB
M	N	O	P	Q	R
LEFOX GREY (MCA) Uplk TACELIS CPC-RMS Uplk	LAMPS III CMD Dnlk	TACJAM (RMS-TJ) Uplk TACJAM (RMS-TJ) Dnlk	AGTELIS (CP to ALQ-133) Uplk AGTELIS (CP to ALQ-133) Dnlk	LAMPS III (CMD) Uplk	CEFLY LANCER (WB) Uplk LEFOX GREY (ACA) Uplk

LP/WB		MP/WB			HP/WB			
S	T	U	V	W	X	Y	Z	AA
LAFAIRE VITE Uplk LAFAIRE VITE Dnlk	LEFOX GREY (MCA) Dnlk TACELIS (CP to RMS) Dnlk	CONDOR Video JSOR Video WALLEYE Video MGGB/EOGB Video	LAMPS III (Acoustic) ASW	LAMPS III (Radar) ASMD	AIDATS Dnlk UPD-X	QSR (IR)	LEFOX GREY (ACA) CELFY LANCER (WB) Dnlk COMPASS BRIGHT Dnlk	PLSS Sensor

Figure A-5. COMPOSITION OF THE 27 DATA LINK GROUPS

APPENDIX B

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APPENDIX C

ABBREVIATIONS AND ACRONYMS

AEQUARE	RPV for long-range surveillance and laser target designation (ARPA/USAF)
AFSATCOM	Air Force Satellite Communications System (USAF)
AGTELIS	Automatic Ground Transportable Emitter Location/ Identification System (USA)
AIDATS	Army Inflight Data Transmission System
ALARM	Alerting Long Range Airborne Radar for MTI (USA) Replaced by SOTAS
ALSS	Advanced Location Strike System (USAF) To be replaced by PELSS
AMQ-23	Radio Sonde Downlink - Meterological Probe (USA) Terminated Program
AN/TPQ-36	Mortar Target Location Information (USA) See Fire Finder
AN/TPS-73	Command and Control of Hawk/Herk Missiles Uses standard Army communications
AQUILA	Mini-RPV for reconnaissance (USA) See ICNS
ASAP	Advanced Survival Avionics Program (USAF)
ASCL	Advanced Sonobuoy Comm Link (USN)
CAC	Control and Analysis Center (USA)
CEFIRM LEADER	Airborne HF Acquisition and Jamming (USA)
CEFLY LANCER	Airborne Emitter Location and Direction Finding System (USA)

CODEM-HF	Long Range Coded Voice and Data (USN) Data Link not defined
COMPASS BRIGHT	Advanced Airborne Remotely Controlled SIGINT System (USAF)
COMPASS EARS	Airborne SIGINT Collection (USAF)
CONDOR	Air to Surface Missile (USN)
DCDRS	Drone Control/Data Retrieval System (USAF) See RMCS
ECOGB	Electro-Optical Glide Bomb (USAF) See GBU-15
FAALS	Field Artillery Acoustic Location System (USA) To use REMBASS data link
FLTSATCOM	Fleet Satellite Comm System (USN)
FIRE FINDER	Location of Hostile Mortars and Artillery (USA) Consists of AN/TPQ-36 and AN/TPQ-37. Uses standard Army communications
GBU-15	Modular Guided Weapon System (USAF) Consists of EOGB and MGGB
GRA-114	Sound ranging link for artillery location (USA)
GUARDRAIL	Remote SIGINT reporting (USA)
ICNS	Integrated Comm-Nav System (USA) Data link to be used in AQUILA
ITACS	Integrated Tactical Air Control System (USN) See JTIDS
ITCS	Integrated Target Control System (USN)
JTIDS	Joint Tactical Information Distribution System (Joint Service) Combination of ITACS and SEEKBUS programs
LAFAIRE VITE	Remote SIGINT collection and transmission (USA)
LAMPS III	Light airborne multipurpose system (USN)
LE FOX GREY	Remote SIGINT data transmission (USA)
LOSTFCS	Line of sight task force communications system (USN)

MGGB	Modular guided glide bomb (USAF) See GBU-15
MULTEWS	Multiple target electronic warfare system (USA) To use standard Army comm
NBDS	Nuclear Burst Detection System (USA)
NOGS	Night Observation Gunship (USMC) Renamed NOS
NOS	Night Observation System (USMC)
OCCULT	Optical Covert Comm Using Laser Transceivers (USN) Data Link not defined
OPSATCOM	Optical Satellite Comm (USN)
PACKET RADIO	Time Sharing Communications Circuits (USA)
PATRIOT	Surface-to-air Weapon Control System (USA) Formerly called SAM-D
PLSS	Precision Location Strike System (USAF)
PEWS	Patrol Early Warning System (USA)
PLRS	Position Location Reporting System (USA)
PMACS	Position Monitoring and Control System
QSR	Quick Strike Reconnaissance (System) (USAF)
QUICK FIX	Helicopter-Borne HF/VHF Communications Jamming (USA)
QUICK LOOK II	Airborne Radar Emitter Location and Identification System (USA)
REMBASS	Remotely Monitored Battlefield Sensor System (USA)
RMCS	Remotely Manned Control System (USAF) Formerly DCDRS
SAM-D	Surface-to-air Weapon Control System (USA) Renamed PATRIOT
SAOCS	Submarine/Airborne Optical Comm System (USN)
SEEK BUS	TDMA Identification, Position, and Status (USAF) Transmission (Incorporated in JTIDS)
SEEK SKY HOOK	Reconnaissance/Intelligence data Transmission System (USAF)

SETAD	Secure Transmission of Acoustic Data (USN)
SOTAS	Stand-off Target Acquisition System (USA)
SURVSATCOM	Survivable Satellite Comm System (USAF)
TACELIS	Tactical Emitter Location and Identification System (USA)
TACFIRE	Tactical Fire and Control System (USA)
TACJAM	Tactical Jamming System (USA)
TASES	Tactical Airborne Signal Exploitation System (USN)
TRD L	Tactical Reconnaissance Data Link (USAF)
TEAL FEATHER	Covert Sub-to-Sub Communication (USN)
TEAL WINC	Covert Ship-Shore, Ship-Ship, Sub-Shore Communications (USN)
TEAL WREN	Over the Horizon (OTH) Sonobuoy Readout (USN)
TEREC	Tactical Electronic Reconnaissance (USAF)
TOS	Tactical Operations System (USA)
UPD-X	Long Range SLAR Transmission (USAF)
WALLEYE	Air Launched Guided Bomb (USN)
WCCM	Wide Band Command and Control Modem

APPENDIX D

GLOSSARY

This appendix contains a glossary of data link terms.

ACA - Airborne Collection Assembly.

A/D - Analog-to-digital conversion.

AJ Techniques - Anti-jam measures that ensure friendly effective use of the electromagnetic spectrum despite the enemy's use of electronic warfare.

Allowable Bit Error Rate - The total number of bits that can be in error for a given total number of bits transmitted without affecting the performance of the data link, e.g., 6 per 10^6.

Amount of Input Power - The prime input power the data link equipment requires from an external power source.

Bandwidth Compression Ratio - The ratio of data compression. Compression is defined as a technique for reducing bandwidth needed to transmit a given quantity of data in a given time or to reduce the time needed to transmit a given quantity of data in a given bandwidth. Ideally, redundant data is reduced or eliminated by this technique.

Baseband - The frequency band containing the signal of interest; in the process of modulation, the frequency band is occupied by the aggregate of the transmitted signals when first used to modulate a carrier. These signals may exist in their source form (analog or digital) or may be encoded into a pulse train for transmission (baseband transmission).

Code - A system of rules and conventions for forming characters, words, blocks, or messages.

Correlation - A detection method by which an incoming signal is compared with an internal reference signal for degree of commonality.

Crypto - An indication that the information bits are transformed in such a way that any covert interception of the bit stream will be unintelligible without the knowledge of the transformation scheme.

D/A - Digital-to-analog conversion.

Data - Material or signals (analog or digital) transmitted or processed to provide information or to control a process.

Data Sink (Sink) - The equipment that accepts data signals after transmission.

Data Source (Source) - The equipment that supplies the data signal to be transmitted.

Decoder - A network or device in which one or more specific outputs result from a prescribed combination of inputs.

Detection - A process by which information is extracted from the received (modulated) data.

Duplexer - A device that is used to switch an antenna for transmit or receive.

Duty Cycle - The percent of active-time-to-total-time that the transmitter/amplifier is operating.

EMC (Electromagnetic Compatibility)- The capability of electronic equipment and systems to operate in the intended environment at designated levels of efficiency without degradation due to unintentional interference.

Encoder - Conversion of analog signal information into a corresponding sequence of coded digital characters, words, blocks, or messages.

Error Correction Type - The coding scheme wherein an error correcting code uses data signals that conform to specific rules of construction so that departures from the construction in the received signals can be detected automatically. It permits the automatic correction, at the received terminal, of some or all of the errors. Such codes require additional signal elements to those necessary to convey the basic information.

Error Detection Type - The coding scheme wherein an error detecting code uses data signals that conform to specific rules of construction, so that departures from this construction in the received signals can be detected automatically. Such codes require more signal elements that are necessary to convey the fundamental information.

EW (Electronic Warfare) - The general title under which AJ, ECM, ECCM, etc., are included.

Family - A collection of data links having a set of common characteristics unique from other families.

Frequency Band - The current letter designator for that portion of the frequency spectrum in which the transmitted bandwidth is included.

IFF - Identification Friend or Foe.

Information Bit Rate - The number of information bits per second that are processed by the receiving platform. Parity and overhead bits are not included.

Link Access Time - Given that the equipment for the communications system is located in its operational environment, link access time is defined as the time required to establish the communications link; e.g., start transmission and reception.

Maintainability - A characteristic of design and installation which is expressed as the probability that an item will be retained in or restored to a specified condition within a given period of time, when the maintenance is performed in accordance with prescribed procedures and resources. The expected time required to localize, isolate, and verify a failure and perform the necessary repair actions, i.e., Mean Time to Repair (MTTR).

Modulation - How some characteristics of the carrier wave are varied in accordance with the instantaneous value of samples of the intelligence to be transmitted.

Multiplexing (Baseband) - A process by which two or more baseband signals are combined into one signal in such a way that the receiver will be able to separate the signals. Each signal must differ from the others in some characteristic which is predictable.

Number of Available Channels - A channel is either a single path for transmitting electric signals, usually in distinction from other parallel paths, or a band of frequencies. "Path" is to be interpreted in a broad sense to include separation physically by frequency division or by time division, with transmission in one direction only or in both directions simultaneously.

Parity Bit - A bit added to a binary code group that is used to indicate whether the number of recorded 1's or 0's is even or odd.

PI - Probability of Intercept Index

Processor AJ Margin - A measure of the ability of the data link to ensure friendly effective use of the electromagnetic spectrum despite the enemy's use of electronic warfare. Usually expressed as a ratio of the power of a defined jammer over the power of the signal containing the information.

Pseudorandom Code - Codes that have ideal (or nearly ideal) cyclic autocorrelation functions; i.e., possess only one maximum, minimize detection ambiguity, and maximize the tolerance of errors in the code.

Range - The maximum distance that may separate the transmitter from the receiver of the data link such that the performance of the link is not degraded below its operational requirements.

Receiver - Equipment that operates on a transmitted signal to reconstruct the original message.

Reliability - The probability that an item will perform its intended function for a specified interval under specified conditions. State the expected operating time between verified failures of the data link, i.e., Mean Time Between Failures (MTBF).

Resolution (Video Only) - The number of lines per frame and number of frames per second of the video image.

RPV - Remote-powered vehicles.

Signals - Detectable physical quantities or impulses (such as voltage, current, or magnetic field strength) by which messages or information can be transmitted.

TDMA - Time Division Multiple Access.

Transmitted Bandwidth - The difference between the lowest and highest frequencies (or frequency spread) present in a transmitted signal.

Transmitted Bit Rate - The number of information bits plus parity and all other overhead bits actually being transmitted via the data link.

Transmitter - Equipment that operates on the message in some way to produce a signal suitable for transmission over the channel.

Transmitter Power (Peak) - The peak power measured after the final state of amplification and before any transmission line power dividers.

Type of Input Power - The frequency and waveform, including number of phases that the input power is required to have.

Up-Converter - An RF amplifier characterized by the frequency of the output being greater than the input.

APPENDIX E

COMMON FILE AND DATA LINK EQUIPMENT FILE
ASSUMPTIONS FOR LIFE CYCLE COST MODEL

This appendix presents the values assumed for the specific variables of the common file and the data link equipment files.

COMMON FILE

1. Base year for proper inflation and discounting (NBYR) = 1975
2. Cost reduction factor due to equipment commonality (COMF) = .9
3. Number of data link vendors producing a given type of data link (NVD) = 2
4. Average DS/BS turnaround time (BMT) = .5
5. Average depot turnaround time (DMT) = .9
6. System spares sufficiency factor [SUF(1)] = 0
7. LRU spares sufficiency factor [SUF(2)] = 1.65
8. SRU spares sufficiency factor [SUF(3)] = .85
9. Minimum number of system spares per organization (XMINS) = 0
10. Minimum number of spares of each LRU type per organizational site (XMINLO) = 0
11. Minimum number of spares each LRU type per DS/GS per DS/GS site (XMINLB) = 0
12. Organizational LRU stocking objective (BSO) = .5
13. DS/GS LRU stocking objective (BSOBL) = 1
14. Depot LRU stocking objective (BSODL) = .5
15. Average LRU order/ship time at organizational level (OSOL) = 2.4
16. Average LRU order/ship time at DS/GS level (OSBL) = 2.35

17. Average LRU order/ship time at depot level (OSDL) = 0

18. Requirements objectives period (ROP) = 12

19. Available hours per year per man at organizational level (PMO) = 2080

20. Productivity of organizational repair personnel (PRODO) = .75

21. Available hours per year per man at DS/GS level (PMB) = 2080

22. Productivity of DS/GS repair personnel (PRODB) = .75

23. Available hours per year per man at depot level (PMD) = 2080

24. Productivity of depot repair personnel (PRODD) = .75

25. Minimum number of repair personnel per organizational site (XMINOP) = 0

26. Minimum number of repair personnel per DS/GS site (XMINBP) = 0

27. Minimum number of repair personnel per depot (XMINDP) = 0

28. Minimum number of support equipments per type per DS/GS site (XMINSEB) = 0

29. Minimum number of support equipments per type per depot (XMINSED) = 0

30. Average first destination charges (XMIL) = 1200

31. Average distance between DS/GS and depot levels (YMIL) = 150

32. Packaging factor (packed weight ÷ unpacked weight) (PACK) = 1.125

33. Shipping cost rate (SHC) = .0013

34. Shipping rate between DS/GS and depot levels (SSHC) = .0009

35. Average cost per page of original documentation (CPP) = 150

36. Average facilities investment cost per DS/GS site (FCB) = 0

37. Average facilities investment cost per depot (FCD) = 0

38. Personnel turnover rate, organization (TRO) = .332

39. Personnel turnover rate, DS/GS (TRB) = .587

40. Personnel turnover rate, depot (TRD) = .500

41. Operator personnel turnover rate (TROP) = 1

42. Average hourly labor rate for organizational repair (OLR) = 6.91

43. Average hourly labor rate for DS/GS repair (BLR) = 6.91

44. Average hourly labor rate for depot repair = 13.55

45. DS/GS support equipment operating cost factor (SECOB) = .05

46. Depot support equipment operating cost factor (SECOD) = .05

47. Minimum annual DS/GS support equipment operating cost (MSEBO) = 1000

48. Minimum annual depot support equipment operating cost (MSEDO) = 5300

49. Average annual holding cost per type of equipment at organization (HOLDO) = 110

50. Average annual holding cost per type of equipment at DS/GS (HOLDB) = 110

51. Average annual holding cost per type of equipment at depot (HOLDD) = 110

52. Portion of average annual DS/GS facilities operating cost attributed to system being analyzed (FOCB) = 0

53. Portion of average annual depot facilities operating cost attributed to system being analyzed (FOCD) = 0

54. Minimum number of operator personnel per organization (XMOPR) = 0

55. Training cost per operator (TCOSP) = 0

56. Average hourly labor rate for operator (OPLR) = 0

57. Operator productivity (PRODP) = .75

Data Link Equipment File

1. First year of system operation (NDYR) = 1978

2. All R&D dollars spent in 1 year (NRD) = 1

3. All equipment of any data link procured by the same service (NJ) = 0

4. Unit cost not broken down into assembly, test, etc. (ASST) = 0

5. All RDT&E combined with production nonrecurring (PNR) in RDCOS1: In-house = RDTE + PNR costs; (AMOR) = 0

6. One data link system on each platform (Q1) = 1 (air and ground treated as separate platforms)

7. One type of platform (Q2 = Q3 = Q4) = 0

8. All data link installations new; no retrofits (QR1) = 0

9. Average monthly operating hours of data link platform = 20 (air) and 100 (ground) (AHR1) = 20 (air) and 100 (ground)

10. Annual frequency of preventive maintenance is 10 times per year (FPM1) = 0.1

11. Average transportation, setup, and access time for maintenance action = 0 for air and ground (PAMHS1) = 0.

12. Average man-hours to remove and replace a data link system is 10.0 (RMHS) = 10.0.

13. Attrition rate on platforms; 1 in 50,000 hours (air); 0 (ground) (CONDS 1) = 0.00005 (air); 0 (ground)

14. Installation cost of data link not considered as a data link cost (COSIV12) = 0.

15. Average man-hours per preventive maintenance action = 0.5 (PMMH1) = 0.5

16. Four DS/GS maintenance sites for each platform (NOB) = 4

17. One organization maintenance site for each ten airborne platforms and one for each ground platform (NOU) = $\left| \frac{\text{NOA (Air)}}{10} \right|$ = NOA (Ground)

18. Half of all failures isolated to the LRU by built-in test equipment (BIT) = 0.5

19. Fraction of LRUs returned to DS/GS which are isolated to LRU level = 0.99 (RTSS) = 0.99

20. Two depots for each platform (NOD) = 2

21. Training cost per organizational repair person = $1000 (TCOSO) = 1000.00

22. Training cost per DS/GS repair person = $2000 (TCOSB) = 2000.00

23. Training cost per depot repair person = $3000 (TCOSD) = 3000.00

24. Two different types of support equipment required at DS/GS (JSEB) = 2

25. Two different types of support equipment required at depot (JSED) = 2

26. No procurement of ECPs included (ECP) = 0.0

27. No program management cost included (PGMI) = 0.0

28. Number of pages of documentation for operation and repair at organizational level = 300 for the aircraft platform and 300 for the ground platform (NPO) = 300

29. Number of pages of documentation for DS/GS level repairs = 500 for the aircraft platform and 500 for the ground platform (NPB) = 500

30. Number of pages of documentation for depot level repairs = 700 for the aircraft platform and 700 for the ground platform (NBD) = 700

31. All inventory items are new (SCRF) = 1.0

32. Total number of inventory coded items = 100 for the simplex air platform, 200 for the duplex air platform, 600 for the simplex ground platform, and 800 for the duplex ground platform (NCPI) = 100, 200, 600, or 800.

33. Average materials cost per maintenance action at organizational level = $1.0 for the airborne platform and $1.0 for the ground platform (OMC) = 1.0.

34. Number of different types of items stocked at the depots is 100 for the simplex air platform, 200 for the duplex air platform, 600 for the simplex ground platform, and 800 for the duplex ground platform (NOID) = 100, 200, 600, or 800

35. Number of different types of items stocked at the DS/GS sites is 50 for the simplex air platform, 100 for the duplex air platform, 300 for the simplex ground platform, and 400 for the duplex ground platform (NOIB) = 50, 100, 300, or 400

36. Number of different types of items stocked at operational levels is 10 for the simplex air platform, 20 for the duplex air platform, 30 for the simplex ground platform, and 40 for the duplex ground platform (NOIO) = 10, 20, 30, or 40

37. No annual O&S management cost (RPM) = 0.0

38. Average man-hours to fault isolate to LRU level, without using BITE = 1.0 at DS/GS and Depot (BMHS) = 1.0, (DMHS) = 1.0

39. No repair of SRUs at DS/GS (RTSB) = 0.0

40. Half of all LRU failures isolated to the SRU level at DS/GS (RTS1) = 0.5

41. SRU level maintenance not considered; average man-hours to isolate failure to SRU level at DS/GS = 2.0, at Depot = 3.0 (NSRU1) = 1, (BMH1) = 2.0, (DMH1) = 3.0, (SRU Name) = DUMMY

[illegible] No common LRUs with other data links (LCOM1) = 1

43. Total cost of data link allocated among LRUs by allocation factor (RUCOS1) = $\frac{\text{LRU Cost}}{\text{Total Cost}}$

44. Average man-hours to remove and replace each of the LRUs = 0.5 (RMH11) = 0.5

45. Average DS/GS materials cost per LRU maintenance action = $50.0 (BMC1) = 50.0

46. LRU attrition rate = 0 (COND11) = 0.0

47. No throw-away LRUs (ITW1) = 0

48 Average materials cost per LRU maintenance action at depot = $100.0 (DMC) = 100.0

49. MTBF of all LRUs assigned to be 2000 hours (MTBF11) = 2000

50. Cost of first item of DS/GF support equipment = $100,000 (USECOSB1) = 100000.0

51. Utilization of first item of DS/GS support equipment = 20% (UTILB1) = 0.2

52. Availability of first item of DS/GS support equipment = 99% (AVALB1) = 0.99

53. Cost of second item of DS/GS support equipment = $50,000 (USECOSB2) = 50000.0

54. Utilization of second item of DS/GS support equipment = 0%
(UTILB2) = 0.1

55. Availability of second time of DS/GS support equipment = 99%
(AVALB2) = 0.99

56. Cost of first item of depot support equipment = $100,000
(USECOSD1) = 100000.0

57. Utilization of first item of depot support equipment = 20%
(UTILD1) = 0.2

58. Availability of first item of depot support equipment = 99%
(AVALD1) = 0.99

59. Cost of second item of depot support equipment = $50,000
(USECOSD2) = 50000.0

60. Utilization of second item of depot support equipment = 10%
(UTILD2) = 0.1

61. Availability of second item of depot support equipment = 99%
(AVALD2) = 0.99

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